The Revolution of Smallsats

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ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
Εθνικόν και Καποδιστριακόν Πανεπιστήμιον Αθηνών
ΙΔΡΥΘΕΝ ΤΟ 1837

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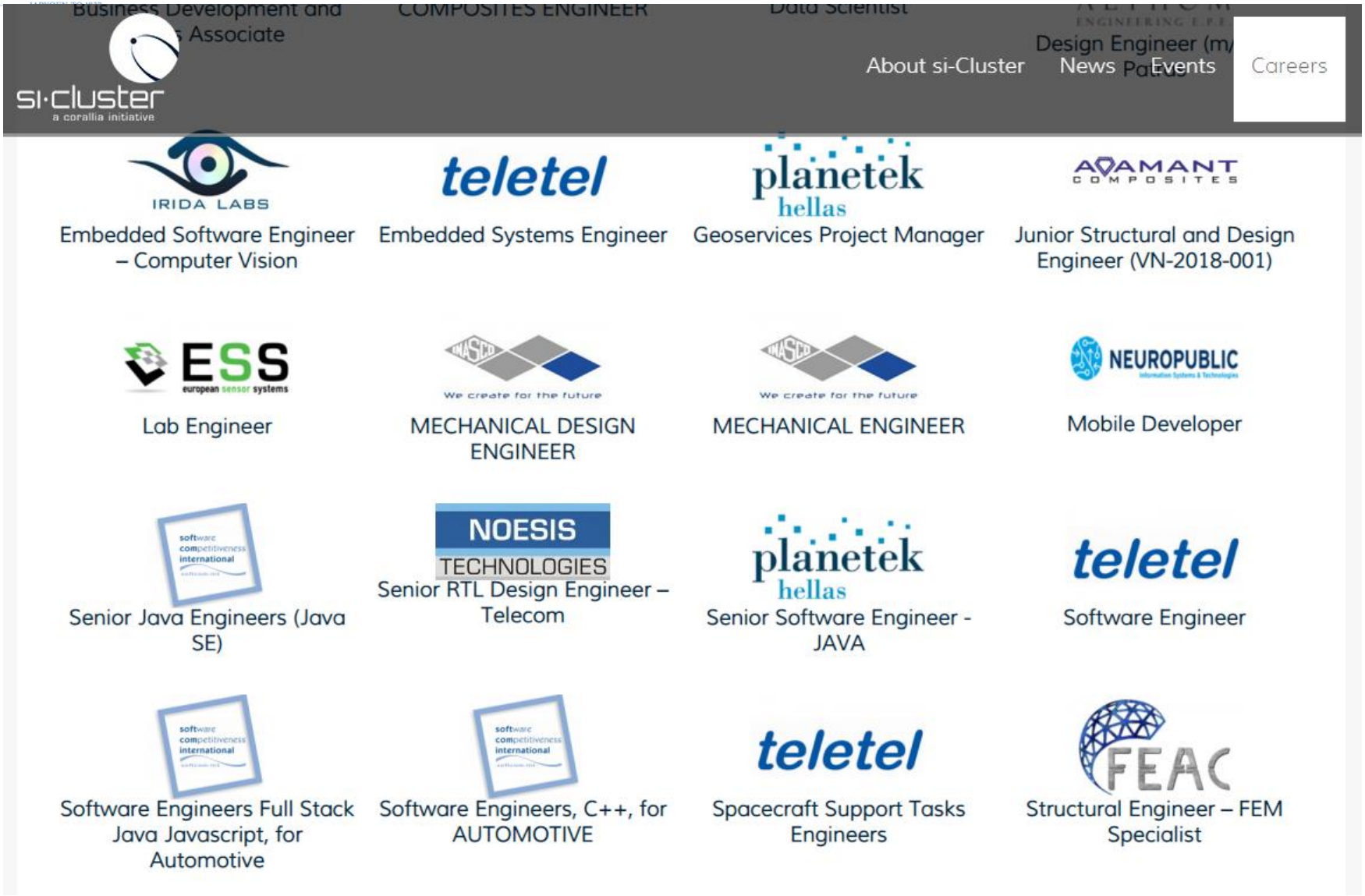
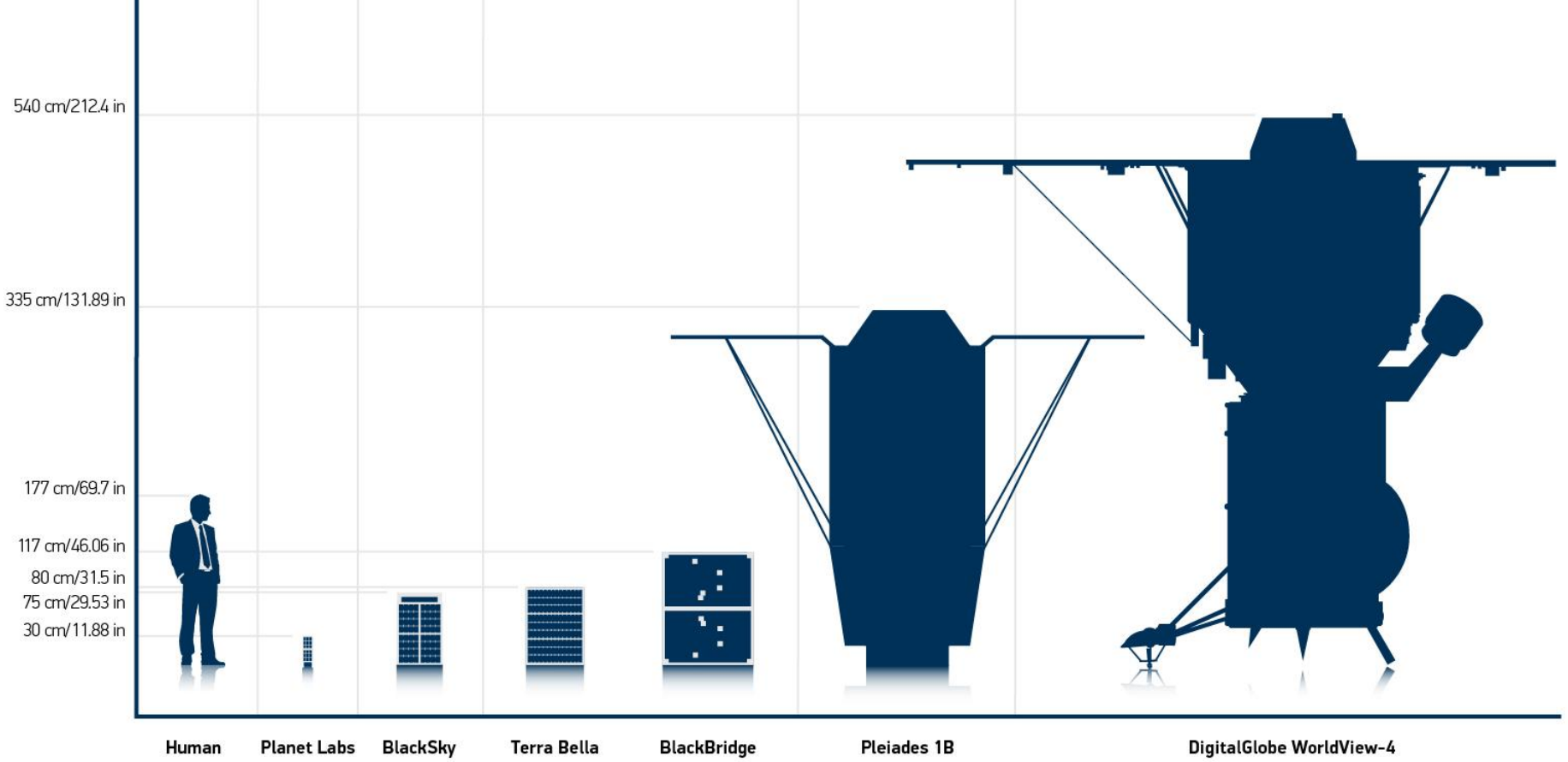
Θέσεις Εργασίας



https://www.si-cluster.gr/en/si-careers.html

Περιεχόμενα

- Εισαγωγή – μικροδορυφόροι
- Πλεονεκτήματα
- Τύποι μικρο-δορυφορικών συστημάτων
- Συστήματα σε λειτουργία – Παραδείγματα
- *NewSpace*



Microelectronics, new materials, sensors, IT hardware have reduced cost, time to manufacture a satellite

Small satellites: easier and quicker to build, affordable to launch

Benefiting from lower launch costs

Small satellites have enabled the development of constellations

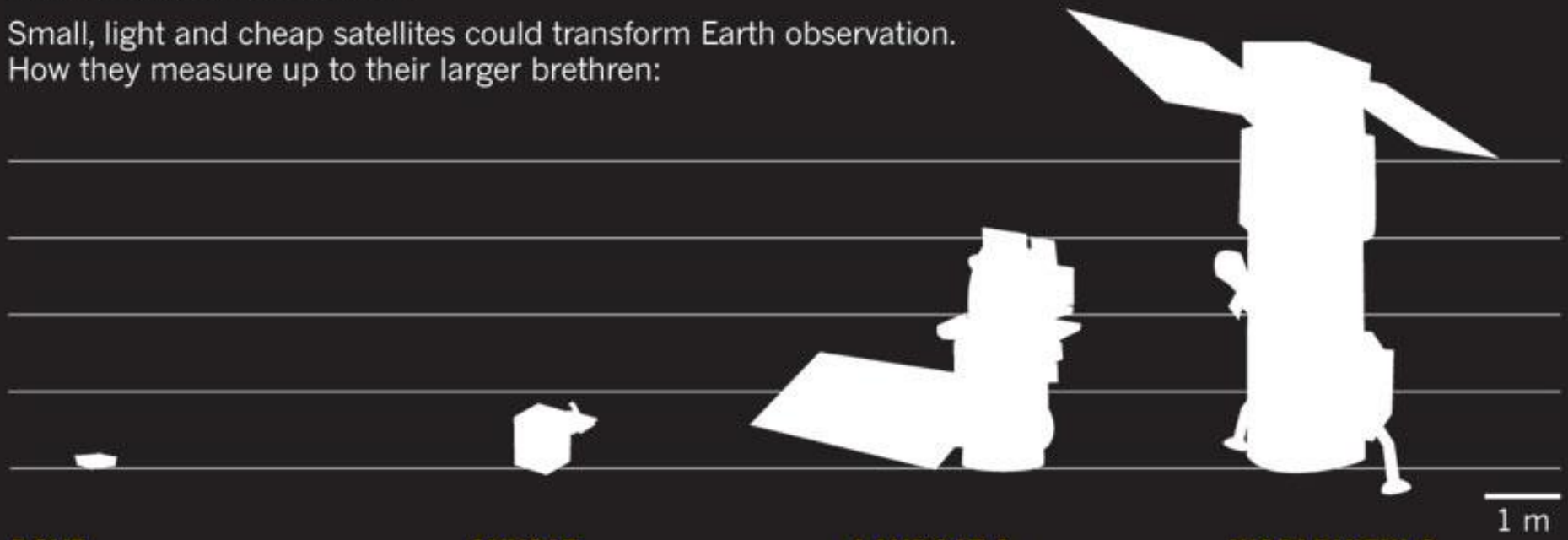
New mission concepts: RADAR, space exploration, space internet

The Small Satellite Revolution

Small Satellites: Size matters

THE SWARM COMETH

Small, light and cheap satellites could transform Earth observation. How they measure up to their larger brethren:



DOVE	SKYSAT	LANDSAT 8	WORLDVIEW-3
Operator: Planet Labs	Skybox Imaging	NASA	DigitalGlobe
Number of satellites*: 32	24	N/A	N/A
Weight: ~5 kg	~100 kg	2,071 kg†	2,800 kg
Instruments: Optical and near-infrared spectral bands	Optical and near-infrared spectral bands	Multiple spectral bands	Multiple spectral bands
Spatial resolution: 3–5 m	~1 m	15–100 m‡	0.3–30 m‡

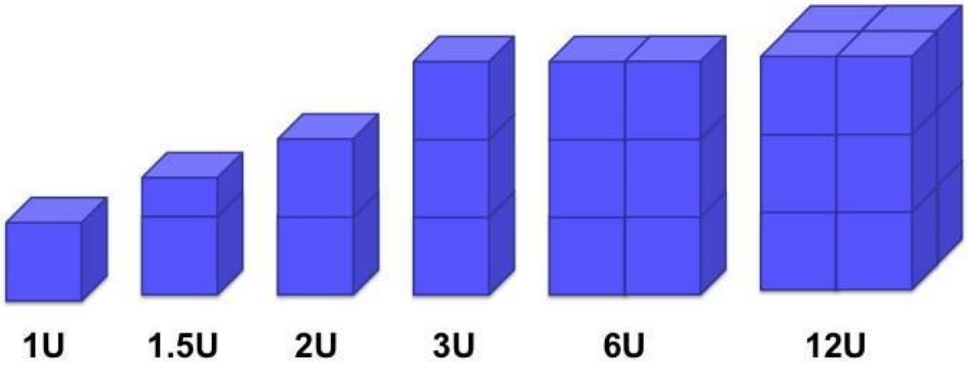
*When fully operational † Without instruments ‡ Depending on spectral frequency

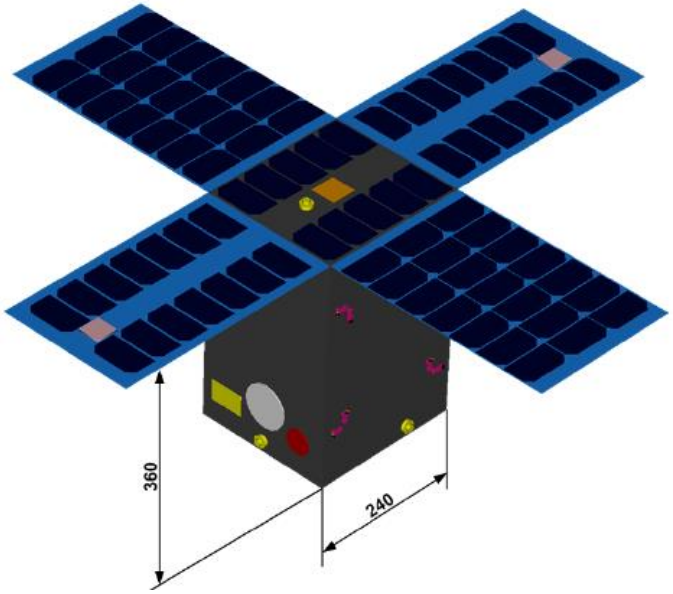
Cubesats/nanosats

Minisatellite, 100-500 kilograms

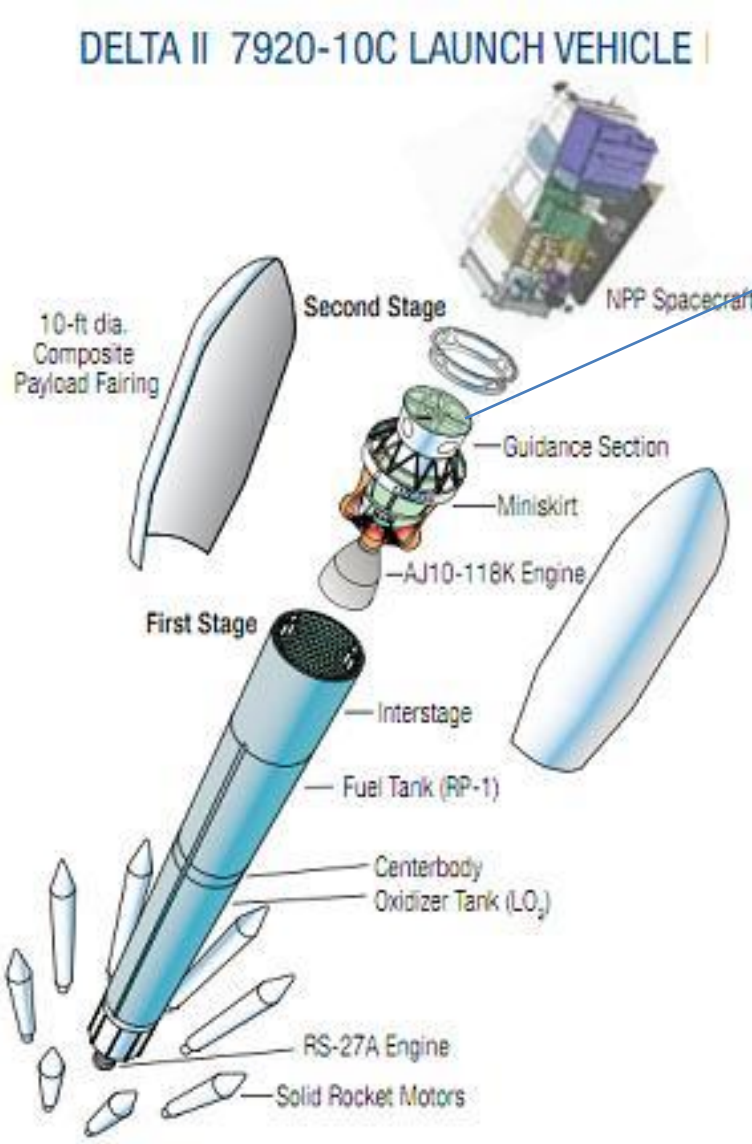
Microsatellite, 10-100 kilograms

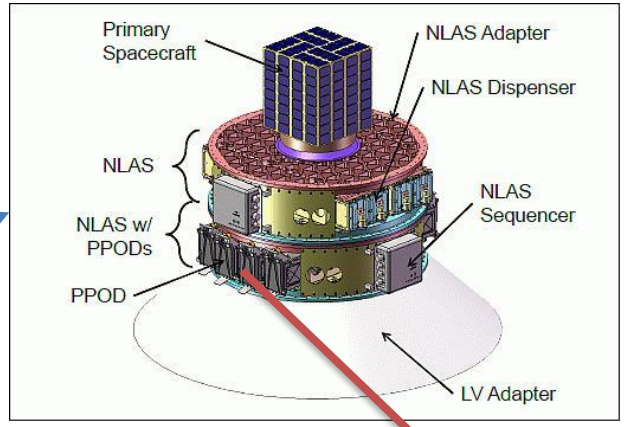
Nanosatellite, 1-10 kilograms

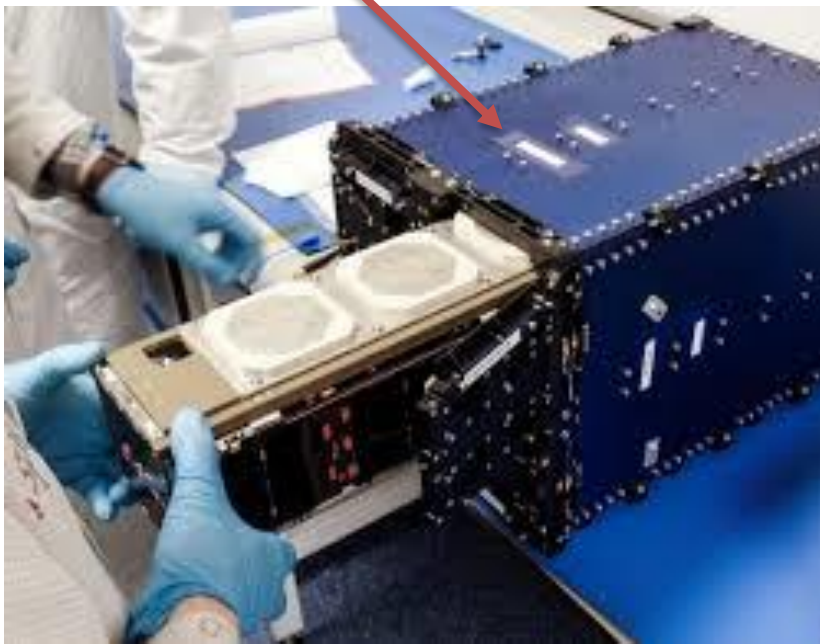




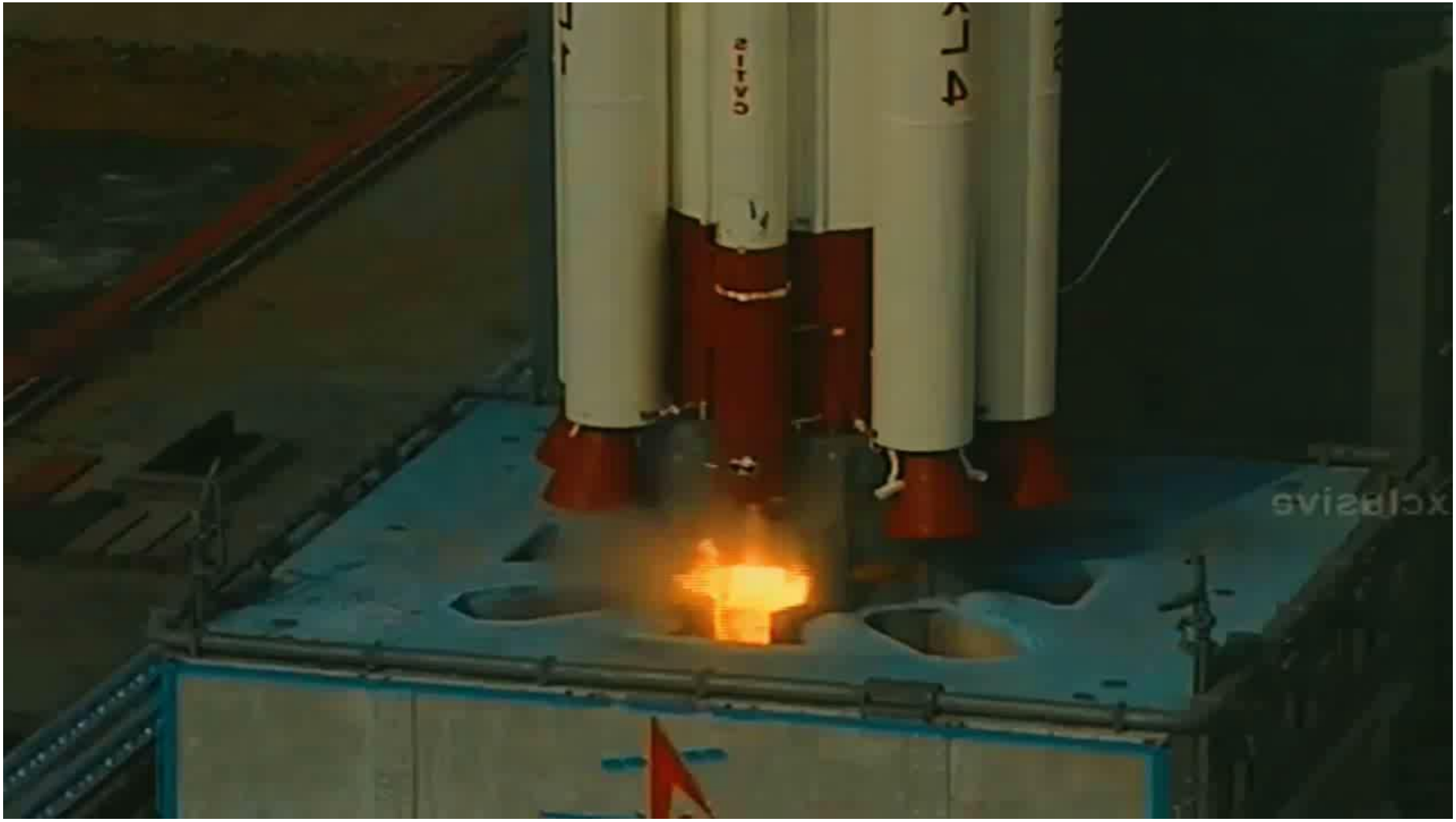
Εκτόξευση νάνο-δορυφόρων







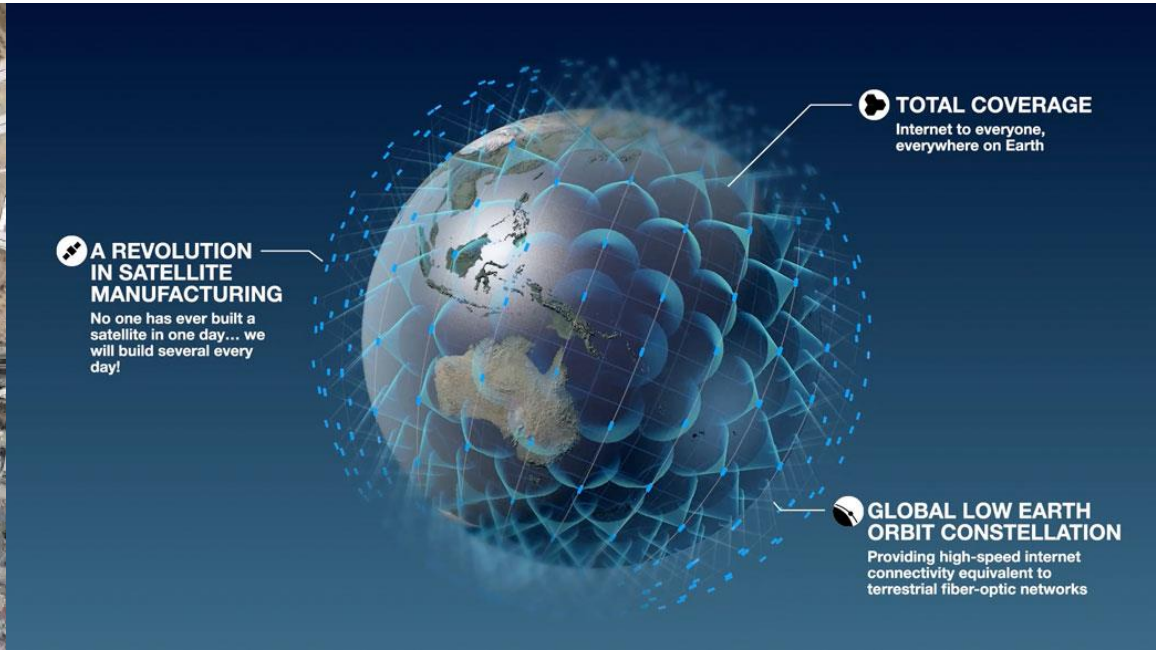
PSLV Nanosat deployment (2017)



Launching Small Satellites - ISS

Εφαρμογές Μικροδορυφόρων

- Τηλε-παρατήρηση
- Τηλεπικοινωνίες/Ίντερνετ
- Ανάπτυξη/πιστοποίηση νέων τεχνολογιών/εφαρμογών



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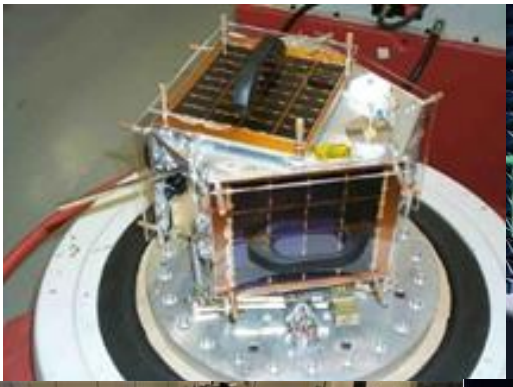
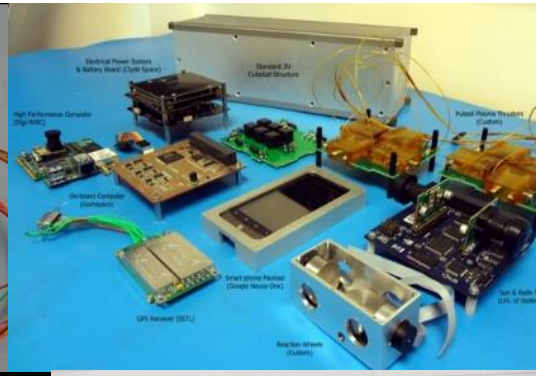
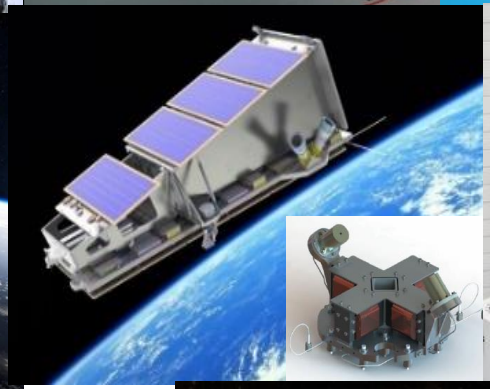
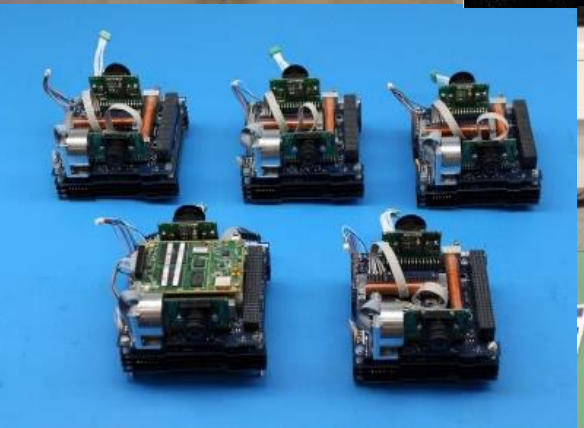
Previous Small Satellite Projects

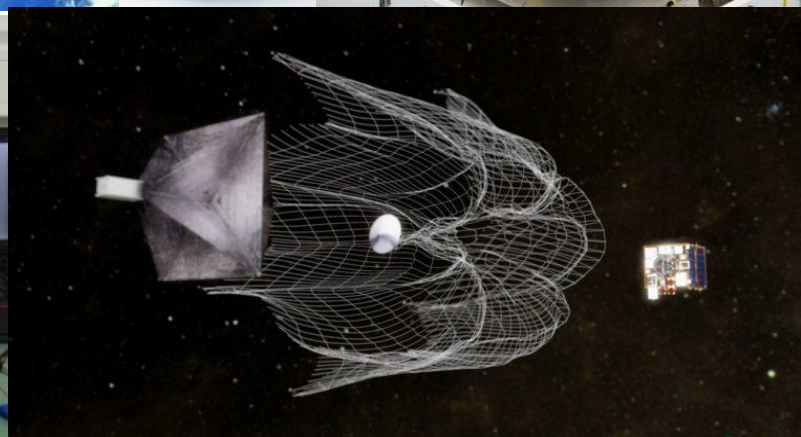








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Small Satellite Constellations
More data/high revisit time

Advantages of Small Satellites

- **Low Cost/use of COTS** (Commercial off The Shelf) microelectronics
- **Common technology with other sectors** (Defence, Robotics, IoT, Mobile Communications, Drones)
- **Short manufacturing time** (< 12 months)
  - Leads to increase of **Return of Investment (ROI)**
  - Science/commercial data return in months from the formation of a project idea
- Small satellite low costs enables **constellations of satellites** which can increase the **revisit time** over a specific area/location, e.g. a 20 cubesat constellation has a revisit time every ~2-4 hours (500 km sun synch)
- **Low launch costs** (secondary payload):
  - 3U Cubesat €100-250,000
  - 50 kg Microsat €1,000,000-2,000,000

Small Satellites – Technology Transfer

- Small satellites are important tools to create space technology capabilities for developing countries, universities or for start ups

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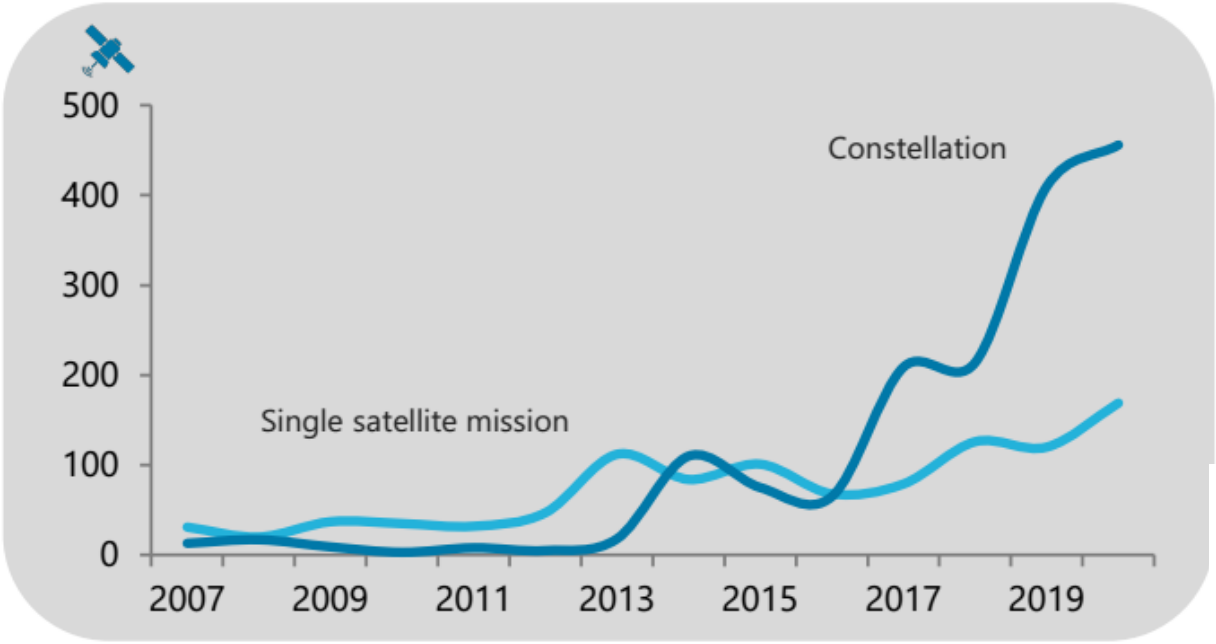
The Business Case of Smallsats

- Small Satellite market: US$ 8.8 bn, > **12% growth annually***
- **1 € spent from the European tax payer** on smallsats, results to a **return of up to 10 €**, a ratio **1:10**



Constellations will account for 70% of the future demand

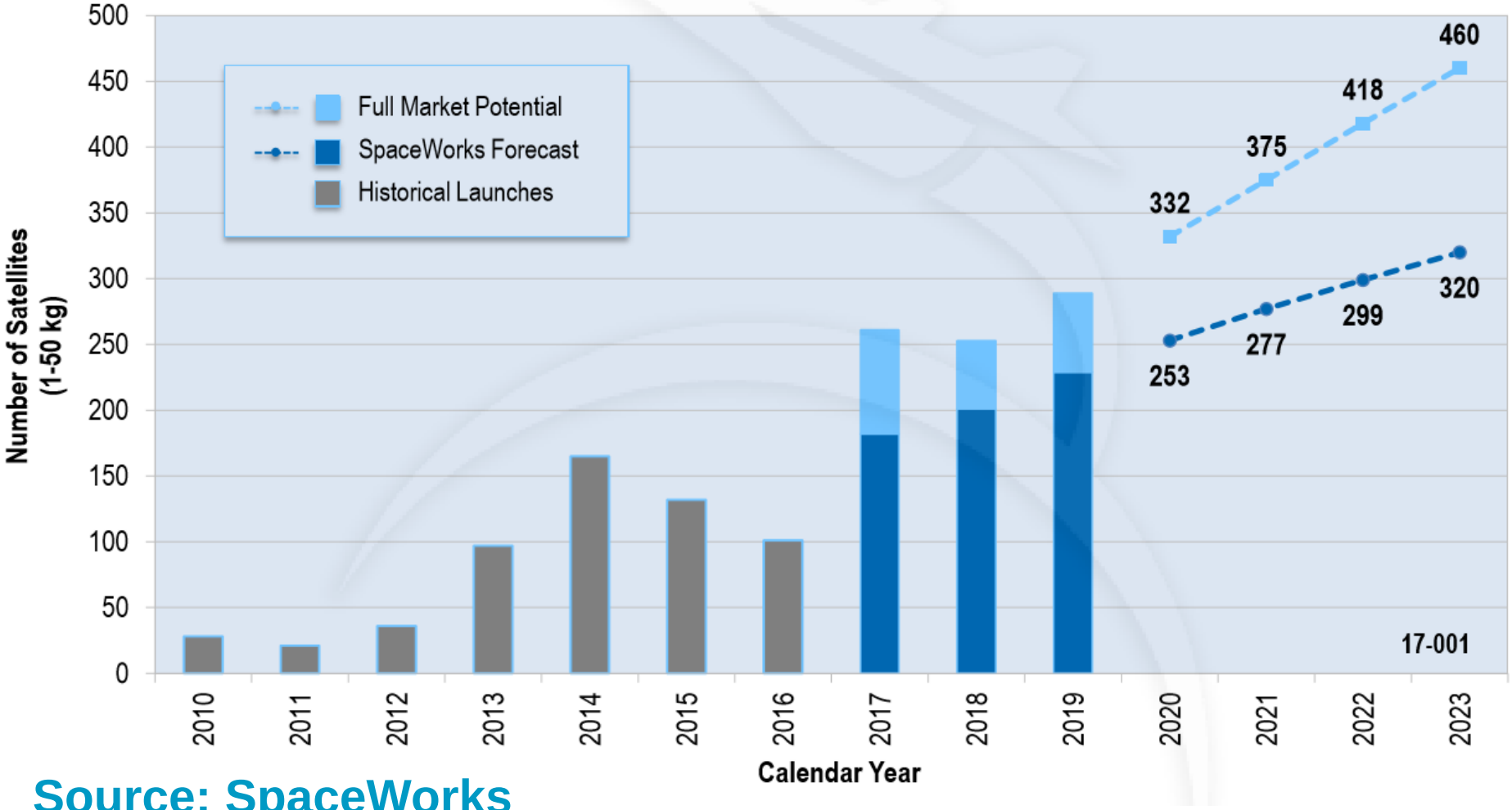
Smallsat demand is experiencing a **x7** increase

*Data from Euroconsult

PROSPECTS FOR THE SMALL SATELLITE MARKET // AN EXTRACT

Ανάπτυξη – Προβλέψεις (Ι)

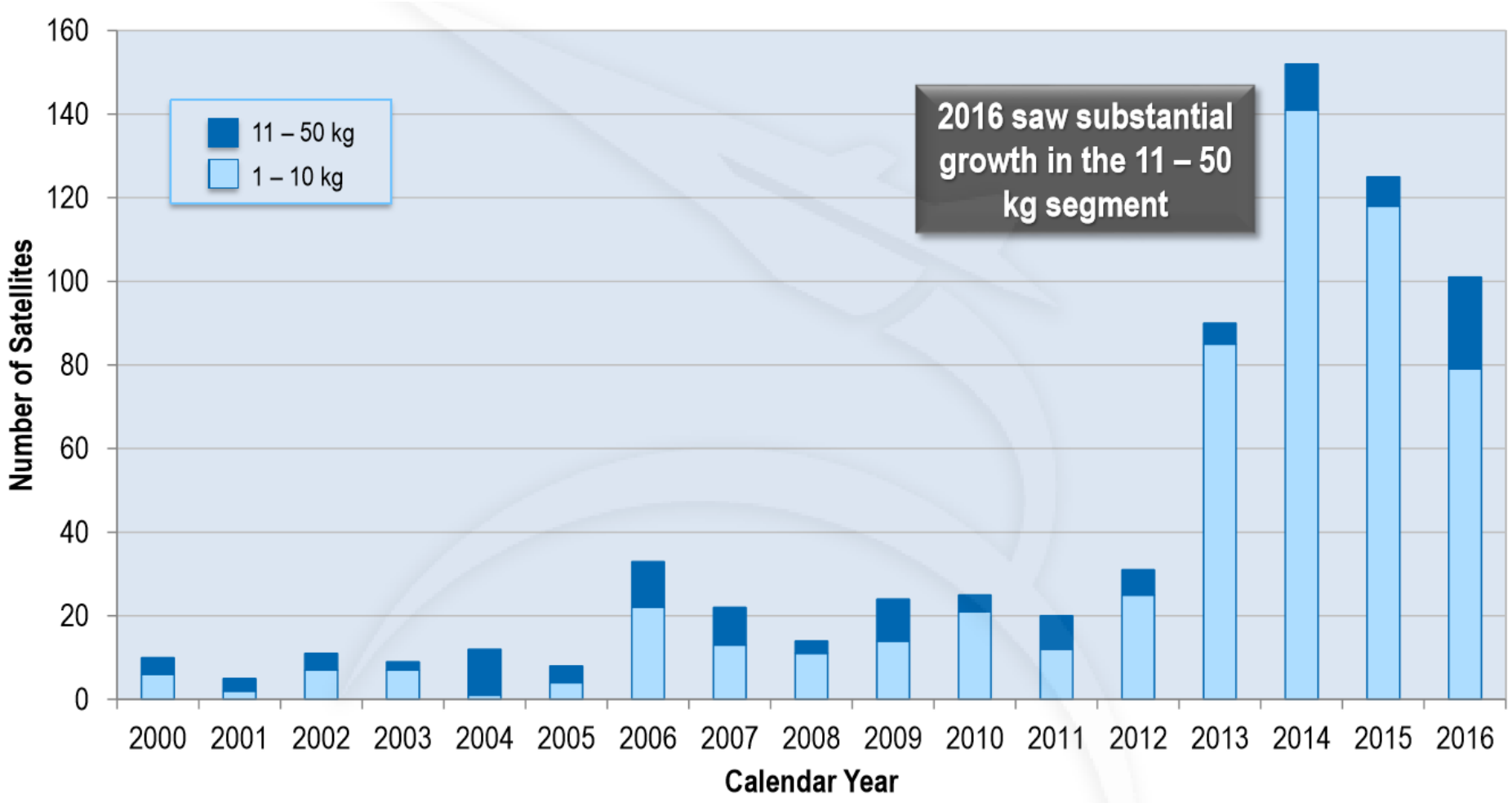
Projections > 2,400 nano/microsatellites will require a launch from 2017 through 2023



Source: SpaceWorks

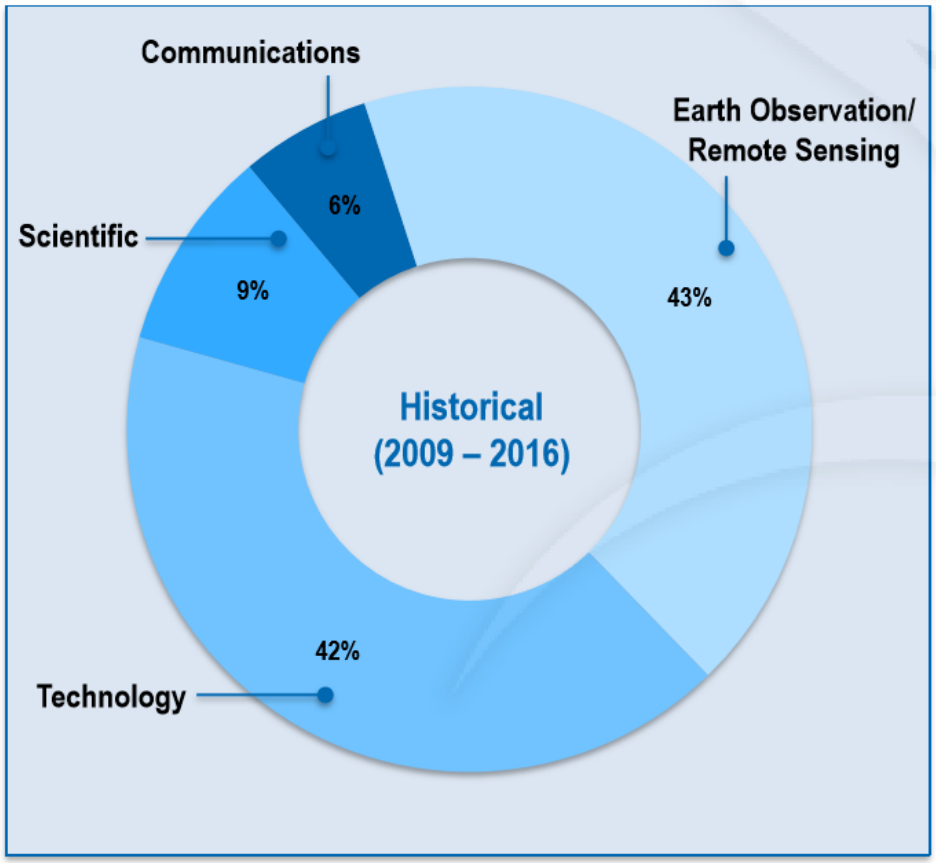
Ανάπτυξη – Προβλέψεις (II)

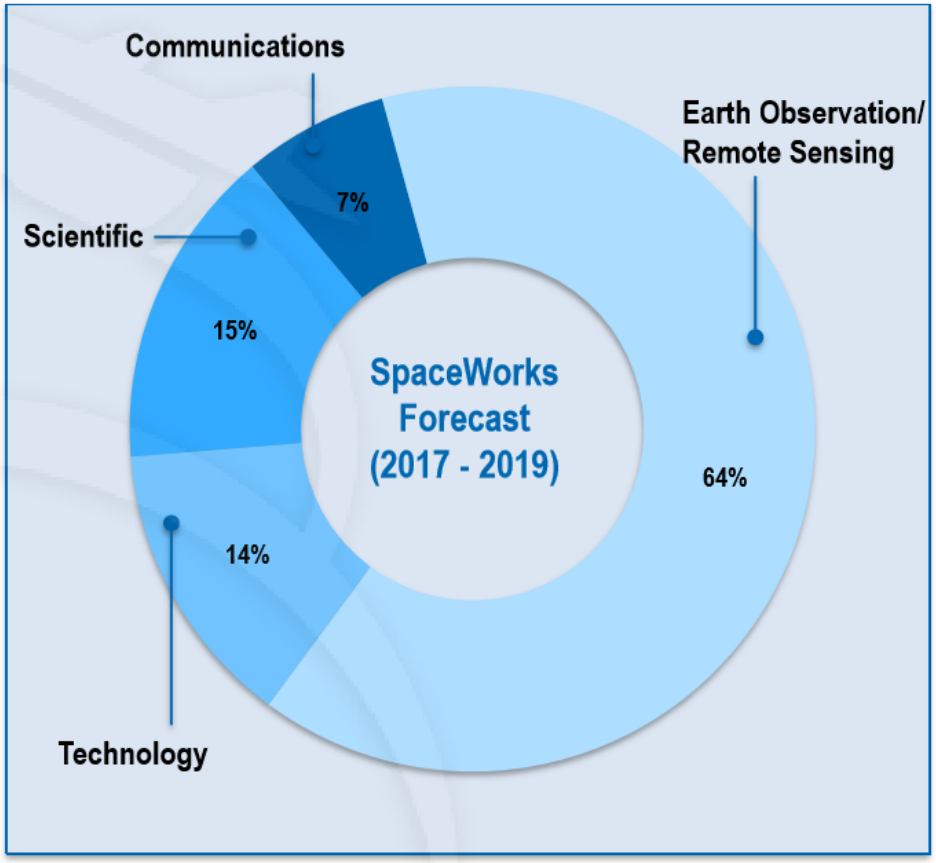
Over 250 small satellites launched in 2017



Source: SpaceWorks

Nano/Microsatellite Trends by Purpose (1 – 50 kg)



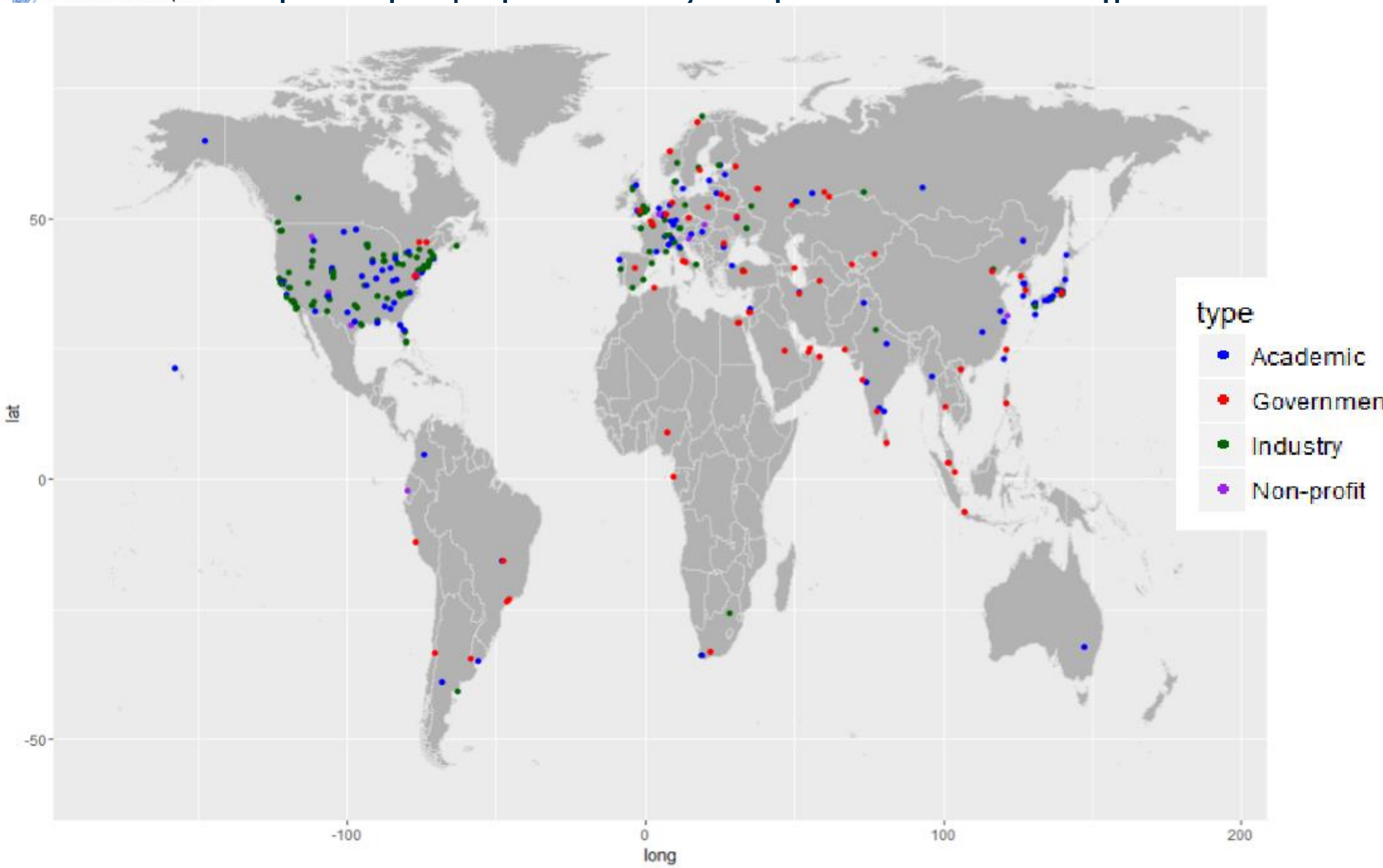


Source: SpaceWorks

Προβλέψεις για την κατασκευή Μικρο/Νάνο-δορυφόρων

- **2,000 – 2,750 nano/microsatellites will require a launch from 2014 through 2020**
- Nano/Microsatellite CAGR (Compound Annual Growth Rate):
  - **Historical average growth of 37.2%** per year over the last years (2009 – 2016)
- Πολλές Start-Ups/SME's εκμεταλλεύονται το χαμηλό κόστος/σύντομο χρόνο παραγωγής κατασκευής (< 12 μήνες) μικροδορυφόρων
  - Οδηγεί στην αύξηση του Return of Investment (ROI)
  - Νέες διαστημικές εφαρμογές small satellites: Internet of Things, space weather, SAR (on a cubesat!), deep space exploration, large earth observation constellations

Μικροδορυφόροι – Αυξανόμενο Οικοσύστημα



~70 countries have smallsats or are part of the smallsat ecosystem

Πλεονεκτήματα Μικρο/Νάνο-δορυφόρων

- **Χαμηλό κόστος κατασκευής/υιοθέτηση COTS** (Commercial off The Shelf) ηλεκτρονικών/μικροεπεξεργαστών
- **Τεχνολογία** (υλικά, υποσυστήματα, ηλεκτρονικά) είναι **εμπορικά διαθέσιμη** και **όμοια** με άλλους τομείς (UAVs, robotics, IoT, microelectronics, mobile comm's)
- **Σύντομο χρόνο παραγωγής κατασκευής** (< 12 μήνες) μικροδορυφόρων
  - Οδηγεί στην αύξηση του **Return of Investment (ROI)**
  - Επιστημονικά/εμπορικά αποτελέσματα σε μόλις 12-24 μήνες από την έναρξη σχεδίασης κατασκευής
- Το χαμηλό κόστος μικροδορυφόρων επιτρέπει την δημιουργία 'συστοιχιών' (**constellations)** που επιτρέπει την **αύξηση της συχνότητας επανεπίσκεψης** (revisit time) πάνω από το ίδιο σημείο, πχ 20 cubesats/revisit every ~2 hours (500 km sun synch)
- **Χαμηλό (σχετικά) κόστος εκτόξευσης** ως δευτερεύον φορτίο (secondary payload):
  - 3U Cubesat €250,000
  - 50 kg Microsat €1,000,000-2,000,000
  - Main Launchers: PSLV (India), VEGA (ESA), SpaceX Falcon 9 (USA), Soyuz/Dnepr (Russia)
  - Ανάπτυξη πολλών νέων διαστημικών εκτοξευτών (New Glenn, Electron etc)
  - **Η τακτική και συχνή πρόσβαση στον Διεθνή Διαστημικό Σταθμό** (ISS) αλλά και η αύξηση του ρυθμού εκτοξεύσεων έχει **μειώσει το κόστος εκτόξευσης**

Venture Capitalist Funding Small Satellites

- Private funding may exceed government funding by an order of magnitude or more
  - – Nearly twice as much venture capital was invested in space in 2015 than the previous 15 years, combined
  - – Non-traditional investors
  - – Coca Cola in OneWeb

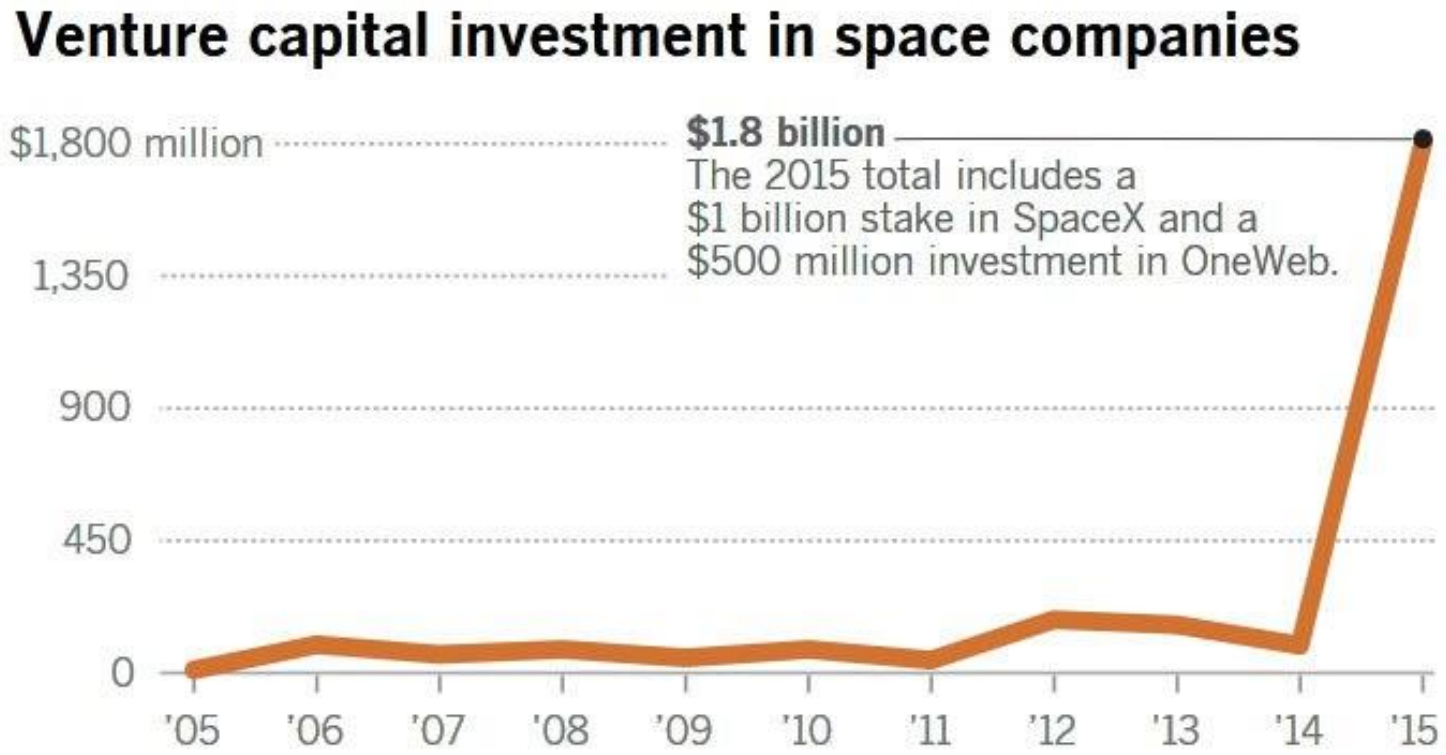
European SME/start ups με VC funding:

- ThrustMe (€14M), France
- IceEYE (€130M), Finland

Company	Venture Capital and Equity Financing through 2016 (Millions)
OneWeb constellation	$1,719
SpaceX constellation	$1,185
Planet constellation	$171
Kymeta	$144
Spire	$67
Spaceflight Industries/ Blacksky	$45
Astroscale	$43

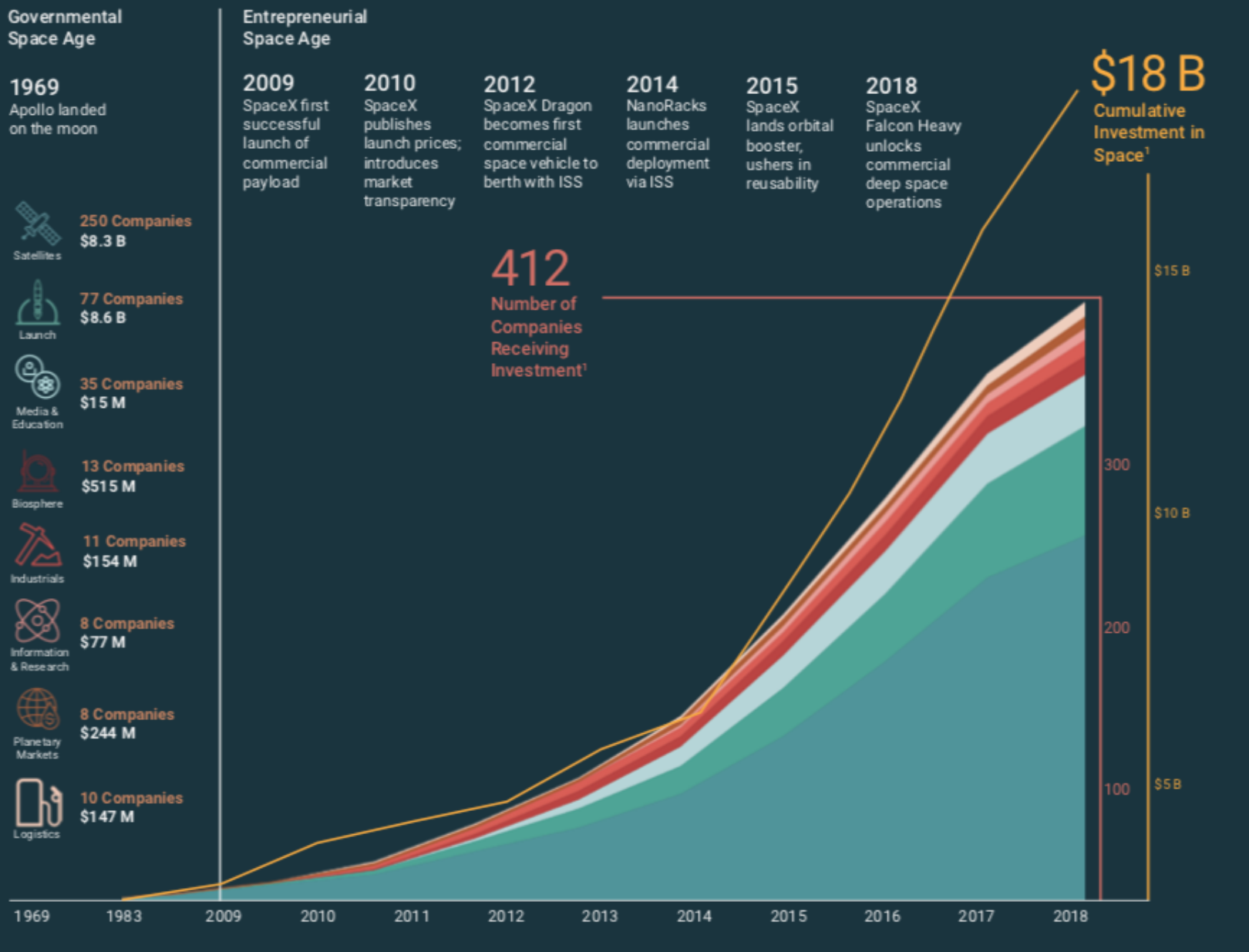
Small Satellite Start Ups – Just some Examples

- Start-up space ventures have attracted over $1.84 billion of investment, since 2000
  - NanoAvionics, Lithuania, cubesat systems, VC >€5 million (2017)
  - D-ORBIT, Italy, deorbiting systems, VC >€2 million (2015-2017)
  - PlanetLabs, USA, cubesats, EO apps, VC > $198 million (2013-2017)



DAWN OF THE ENTREPRENEURIAL SPACE AGE

Equity Investments From 2009 To Present



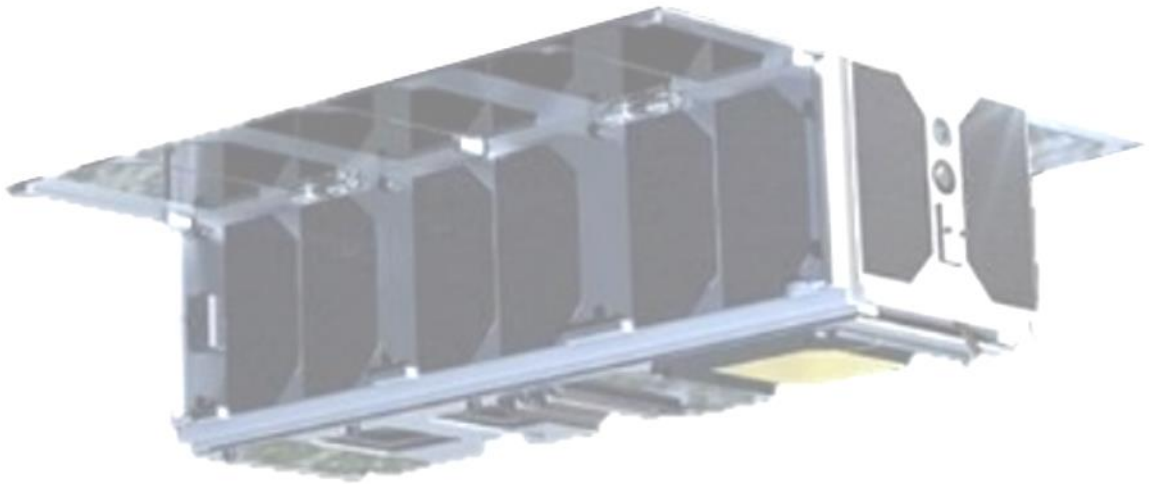
Small Satellite Start Ups – Just some Examples

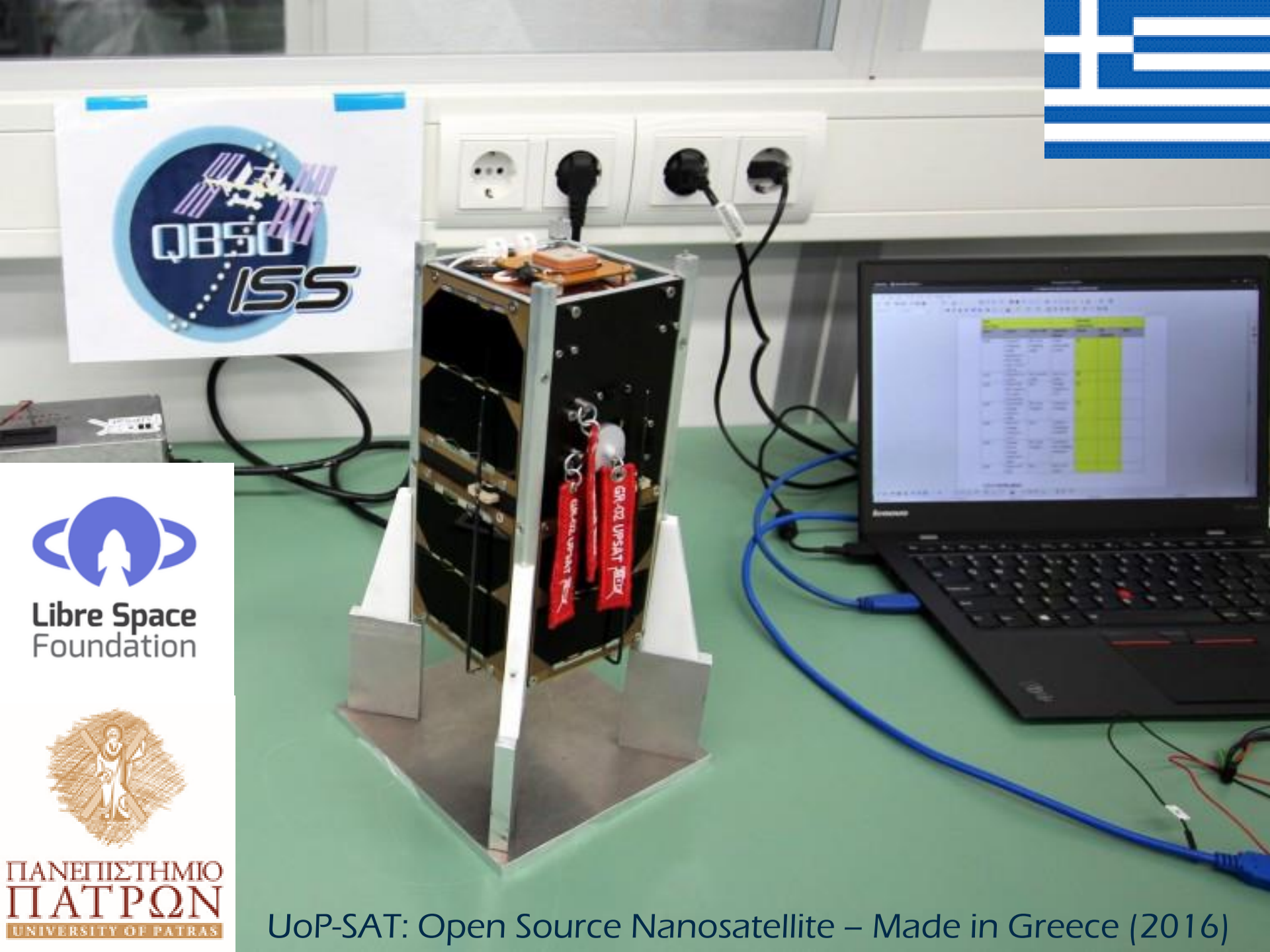
- ThrustMe, France, micropropulsion, VC >€5 million (2017)
- NanoAvionics, Lithuania, cubesat systems, VC >€5 million (2017)
- D-ORBIT, Italy, deorbiting systems, VC >€2 million (2015-2017)
- PlanetLabs, USA, cubesats, EO apps, VC > $198 million (2013-2017)
- SPIRE, USA/Luxemburg, weather info, VC > $139 million (2015-2017)
- SATELLOGIC, USA, Earth Observation, VC > $31.5 (2017)

- Space VC Investors: Draper Fisher Jurvetson, O'Reilly AlphaTech Ventures, First Round Capital, European Investment Fund, CrunchFund, FundoPitanga, Tencent Holdings, Lockheed Martin Ventures

- **VC investment is small in VC/finance standards (10's of millions vs billions), but these investments are HUGE for the space industry/start ups**

Small Satellite Mission Examples

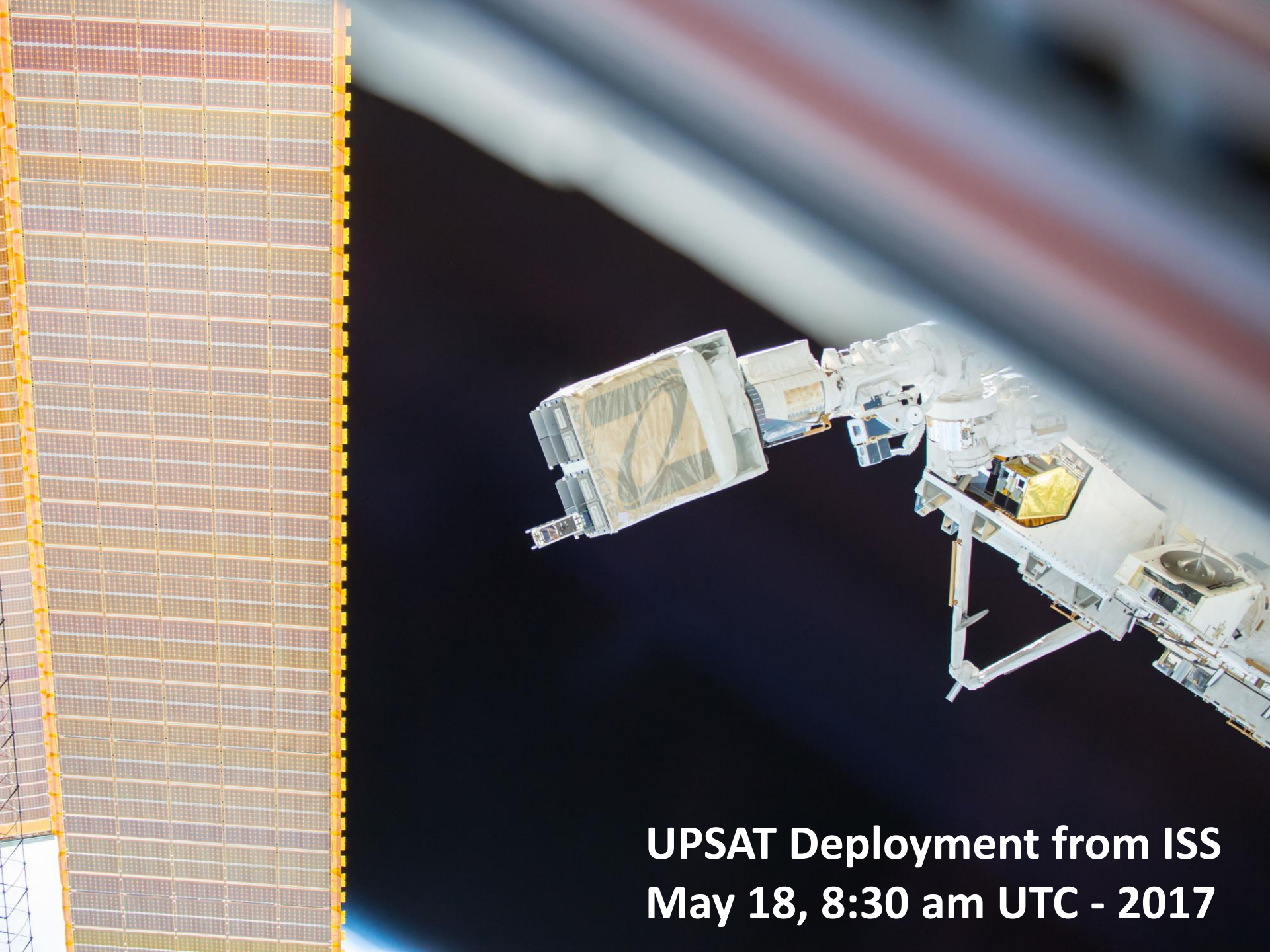




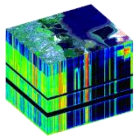
Libre Space Foundation

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ
UNIVERSITY OF PATRAS

UoP-SAT: Open Source Nanosatellite – Made in Greece (2016)


UPSAT Deployment from ISS
May 18, 8:30 am UTC - 2017

Archimedes



Unravelling Earth's Secrets

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Archimedes

A Low Cost, Innovative, Hyperspectral Cubesat Mission

Project Team

UNIVERSITY OF PATRAS
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ

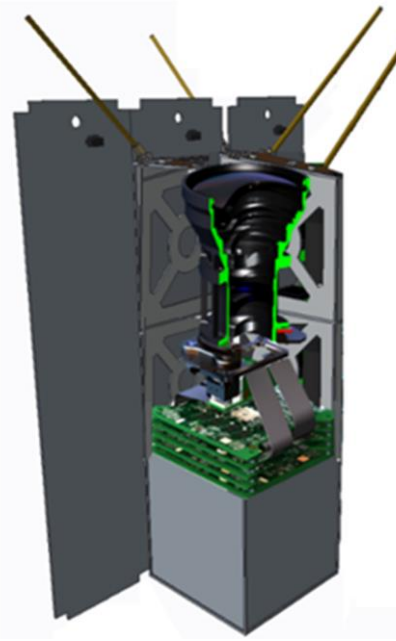
ADAMANT COMPOSITES

ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ ΑΘΗΝΩΝ
NATIONAL OBSERVATORY ATHENS

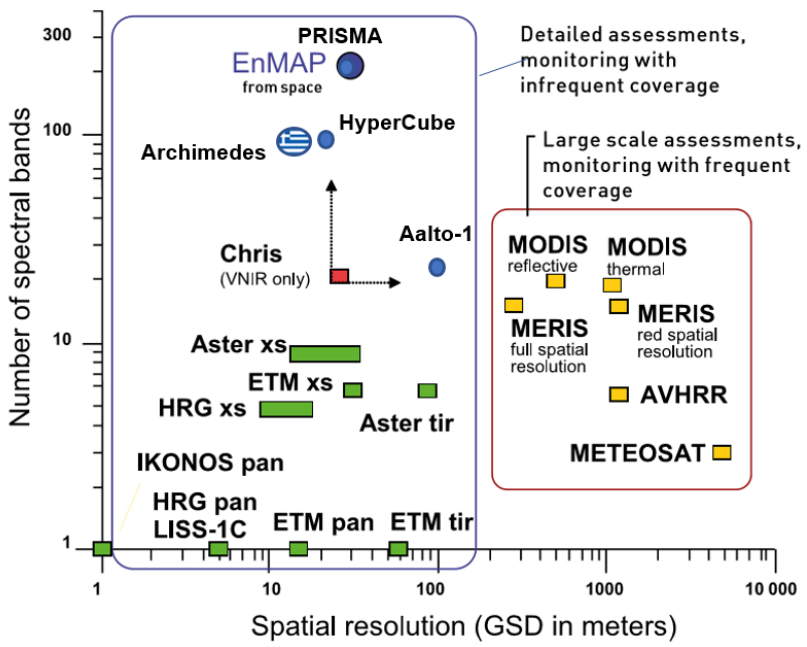
iABG

上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

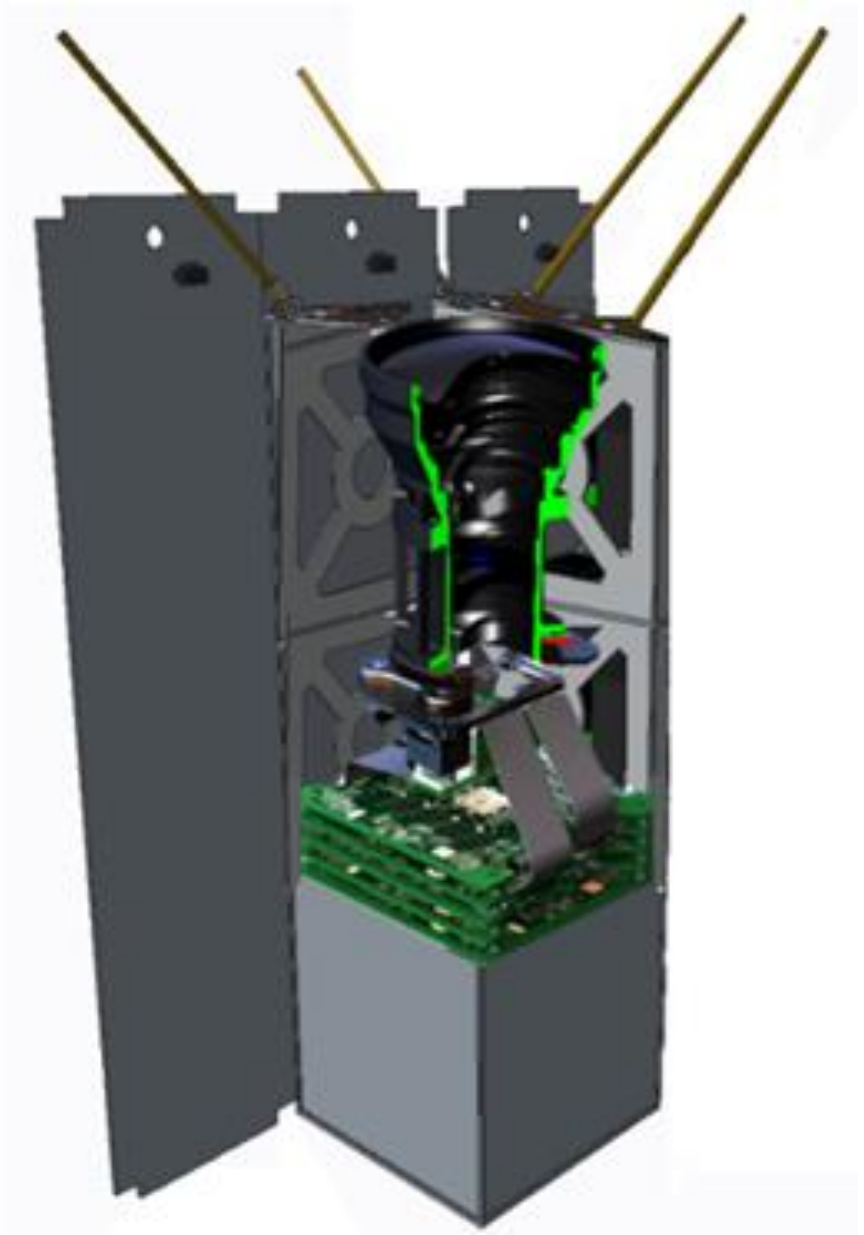
SCS space



Archimedes Mission **Technical Description**



Parameter	Value
Platform Size/Mass	3U, 5 kg
Spatial Res. (450 km)	15 m
Swath (450 km)	15 km
No. Spectral Bands	100
Spectral Range	470-900 nm
Pointing Accuracy	<0.1 deg RMS all axes
Transceiver VHF/UHF	9600 Up/1200bps Down
High Speed X-band	50-100 Mbps
Solid State Storage	1.5-2 TB
Power (Ave)	< 20W



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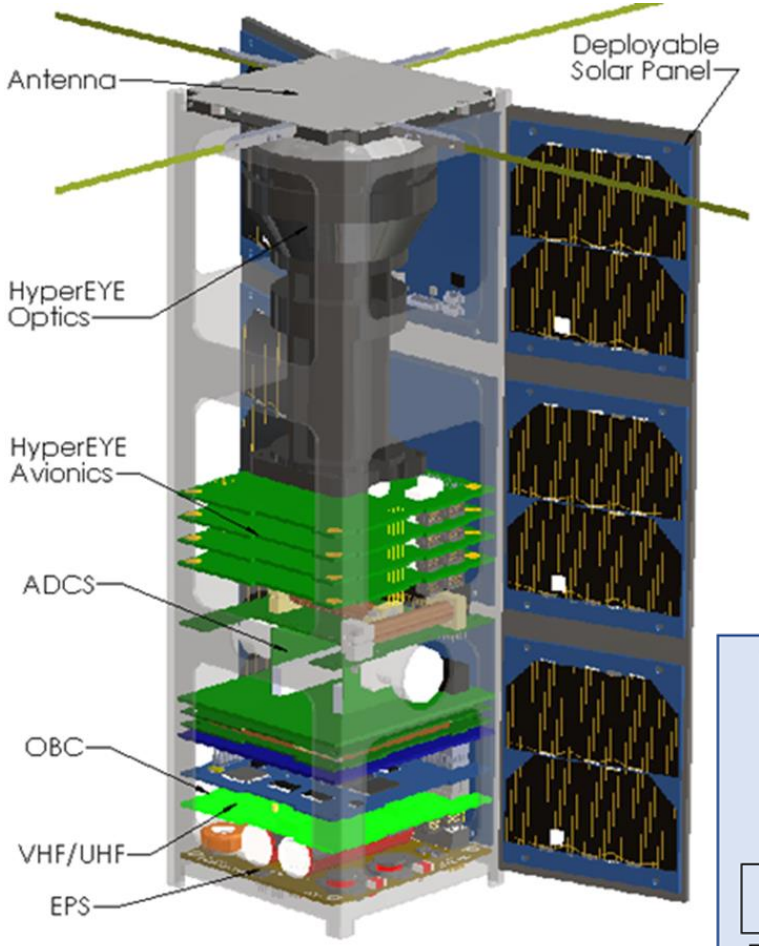
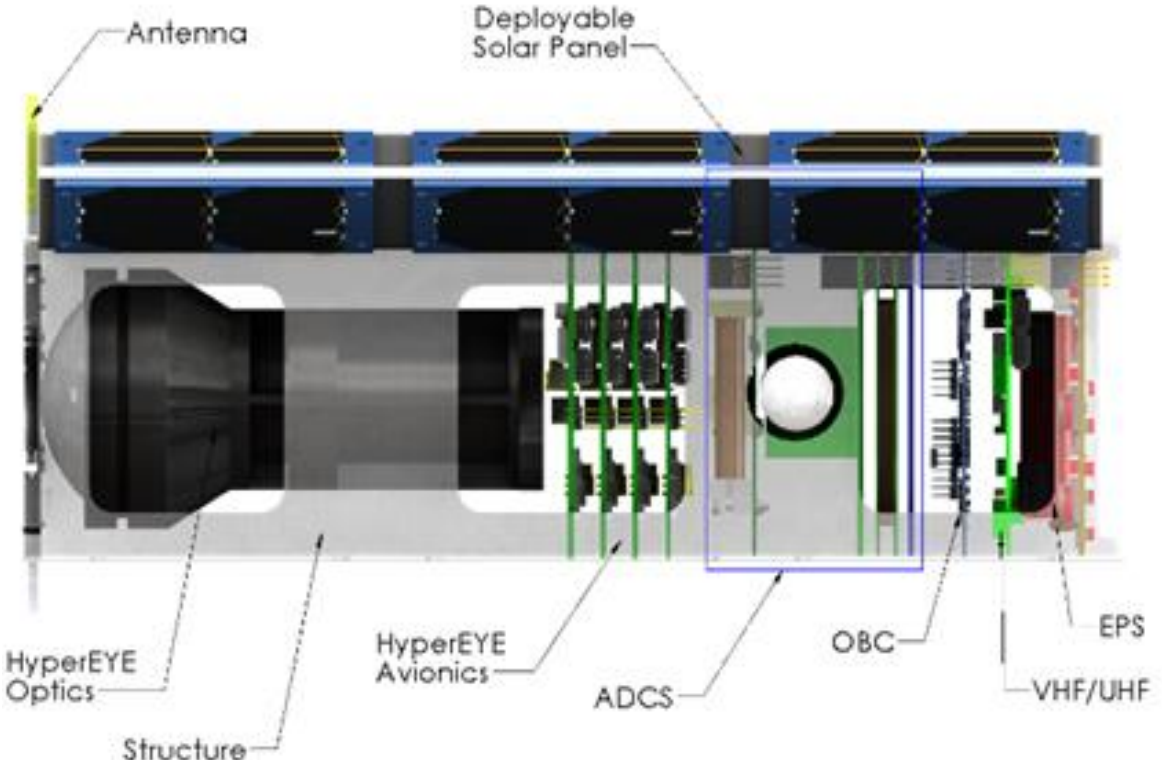
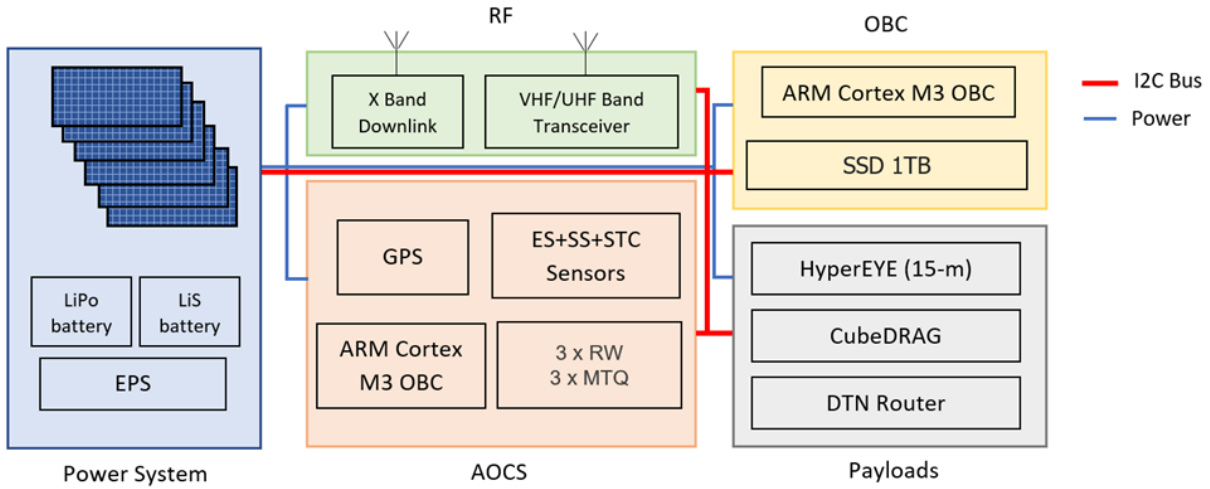
Archimedes Cubesat Platform Design



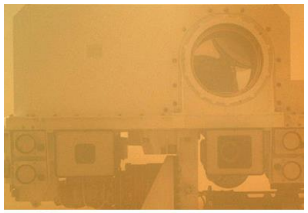


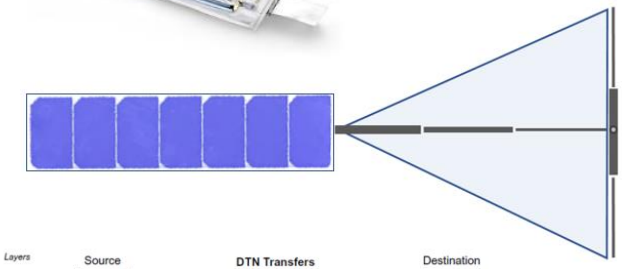


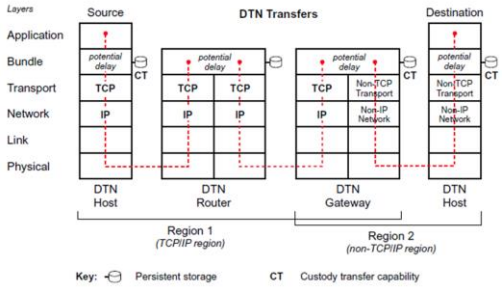
Ground Segment

Game changing Innovations

- An autonomous, super compressed on-board chain to select, compress hyperspectral data: High volume data storage (SAMSUNG SSD), Image compression/processing (ARM, ALMA Technologies)
- An X-Band downlink capability to transmit high volume data (50-100 Mbps)
- High Specific power LiS Battery (400W/kg)
- Low cost drag sail for deorbiting CubeDRAG
- An innovative Delay Tolerant Network (DTN) router payload (CCSDS compatible)



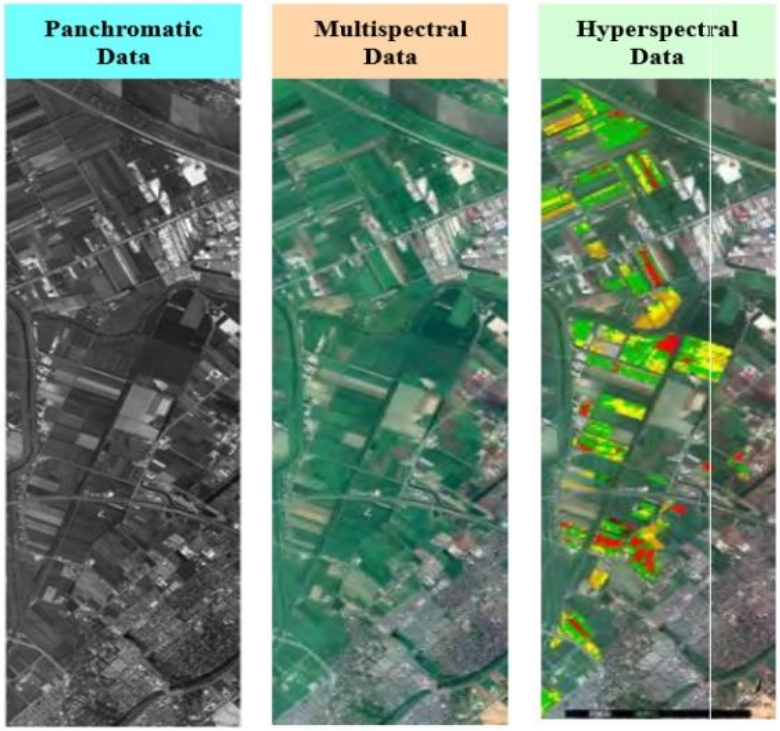


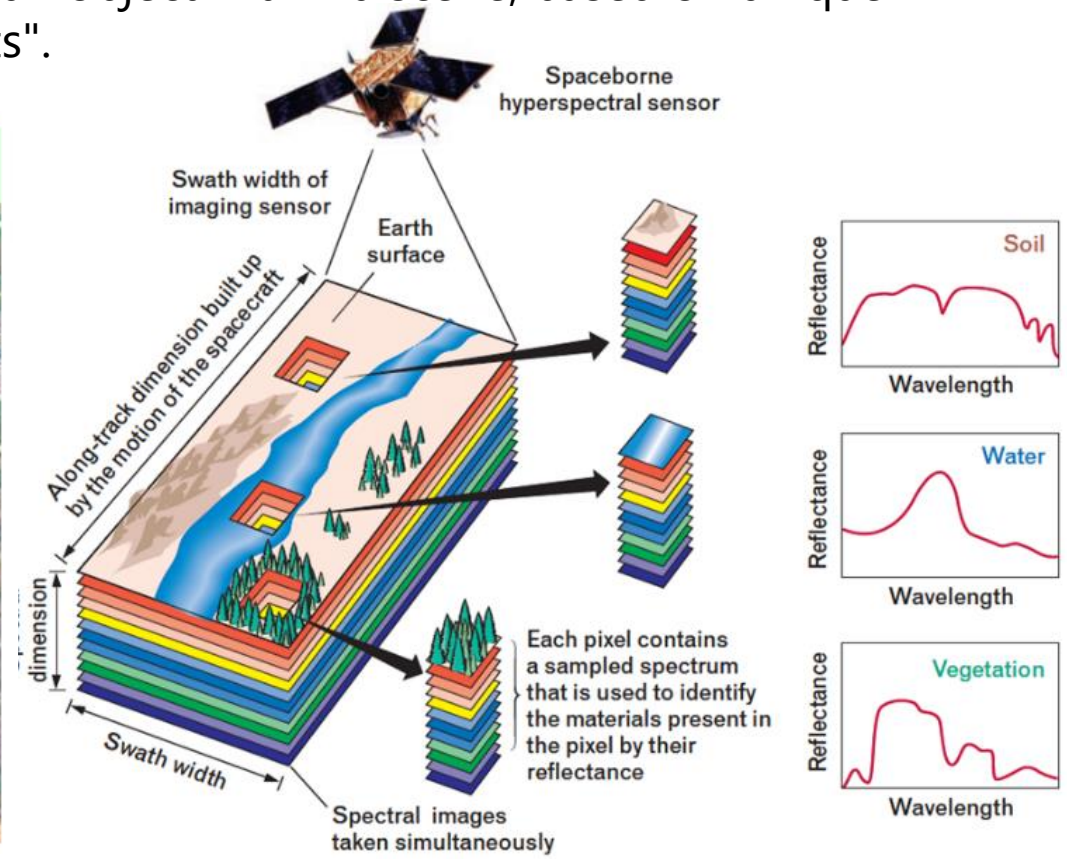


The Science Case: Complementing the Sentinels

Hyperspectral Imaging

- Hyperspectral data contains both spatial and spectral information from materials within a given scene.
- Pixels are sampled across many narrowband images at a spatial location within the "spectral cube", resulting in a one-dimensional spectrum.
- Used to identify and characterize an object within a scene, based on unique spectral signatures or "fingerprints".





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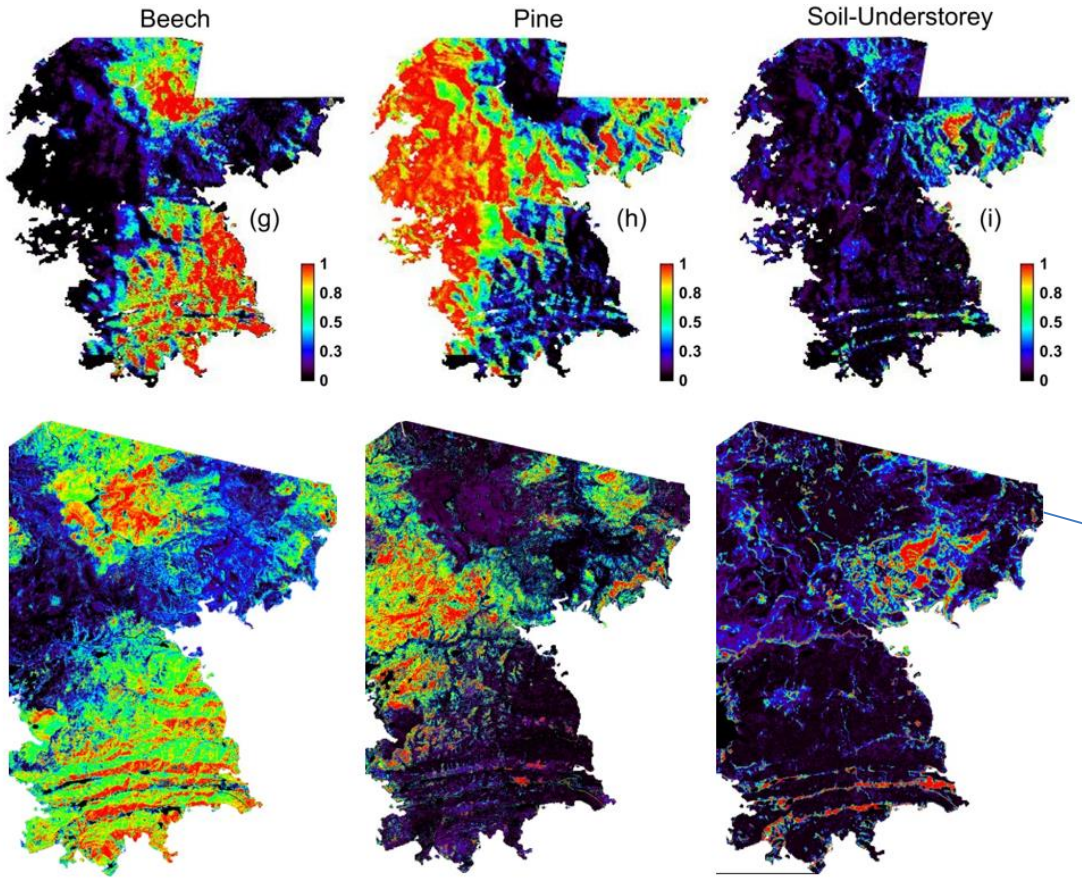
Archimedes **Added Science Value** to **Copernicus**

- The combination of high spectral and spatial resolution of HyperEYE is expected to result in **new unprecedented detailed, accurate vegetation maps.**

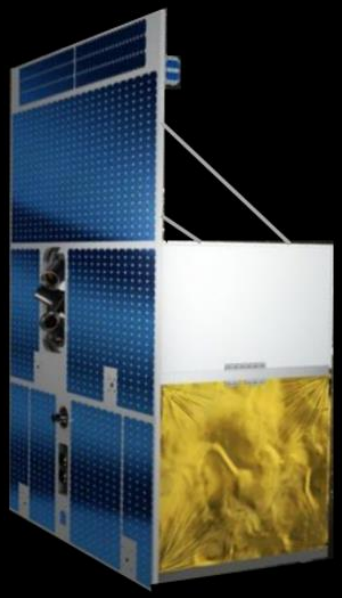
Pindus National Park maps (produced by National Observatory of Athens team)



Forest species abundance maps (beech, pine and understorey/soil) using CHRIS/PROBA hyperspectral (spatial resolution 34m)

Sentinel-2 based abundance maps (spatial resolution 10m)

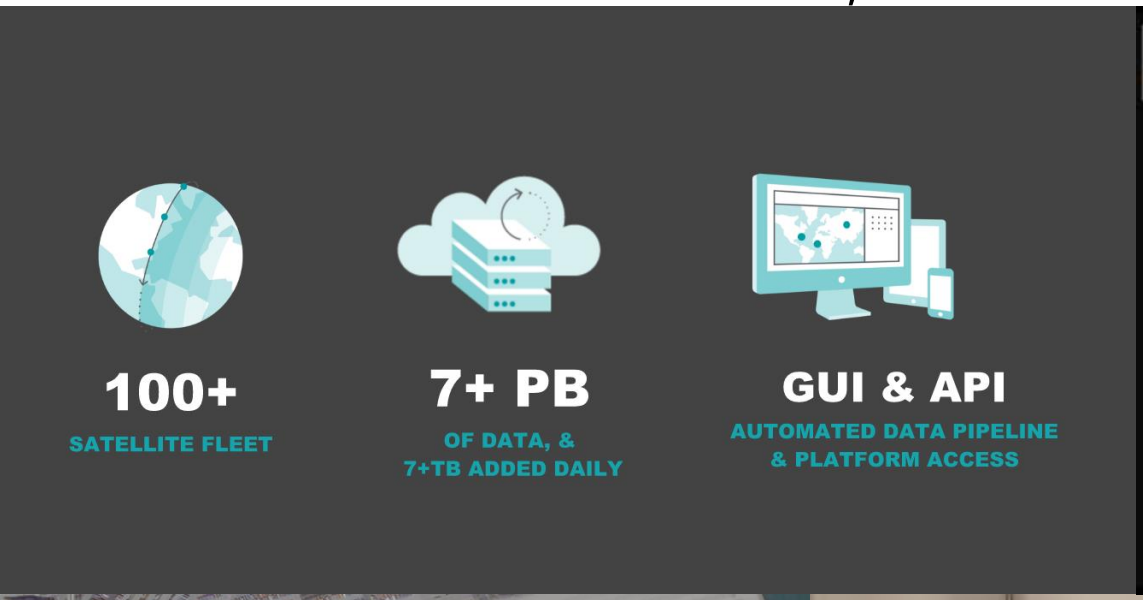
Archimedes: A Space Technology Catalyst

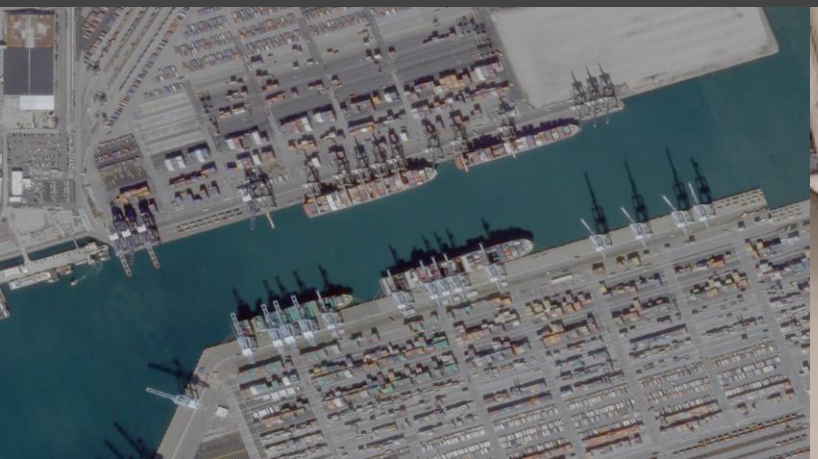


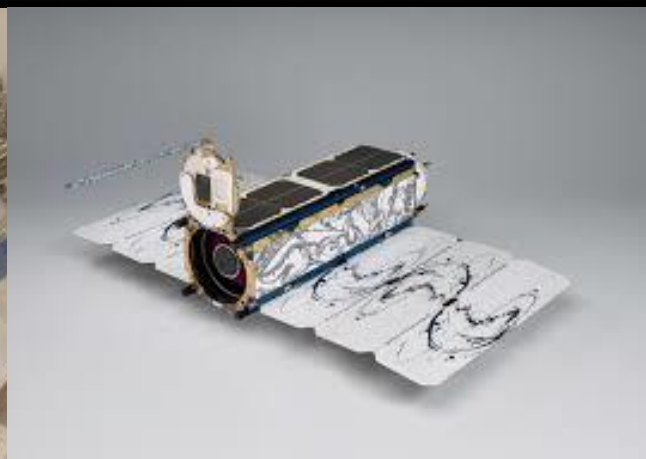
Satellite	**Archimedes** Archimedes	**EnMAP** EnMAP	**Sentinel-2A** Sentinel-2
Mass (kg)	5	970	1140
GSD (m)	15	30	30-60
Storage (GB)	1512	512	2400
Data Rate (Mbps)	100	320	560
Cost (€M)	<0.5	90	195
Dev. Time (Yrs)	<1	12	8

PLANET Labs (USA)

- > 180 3U Cubesats in orbit, 4-5m resolution, Earth

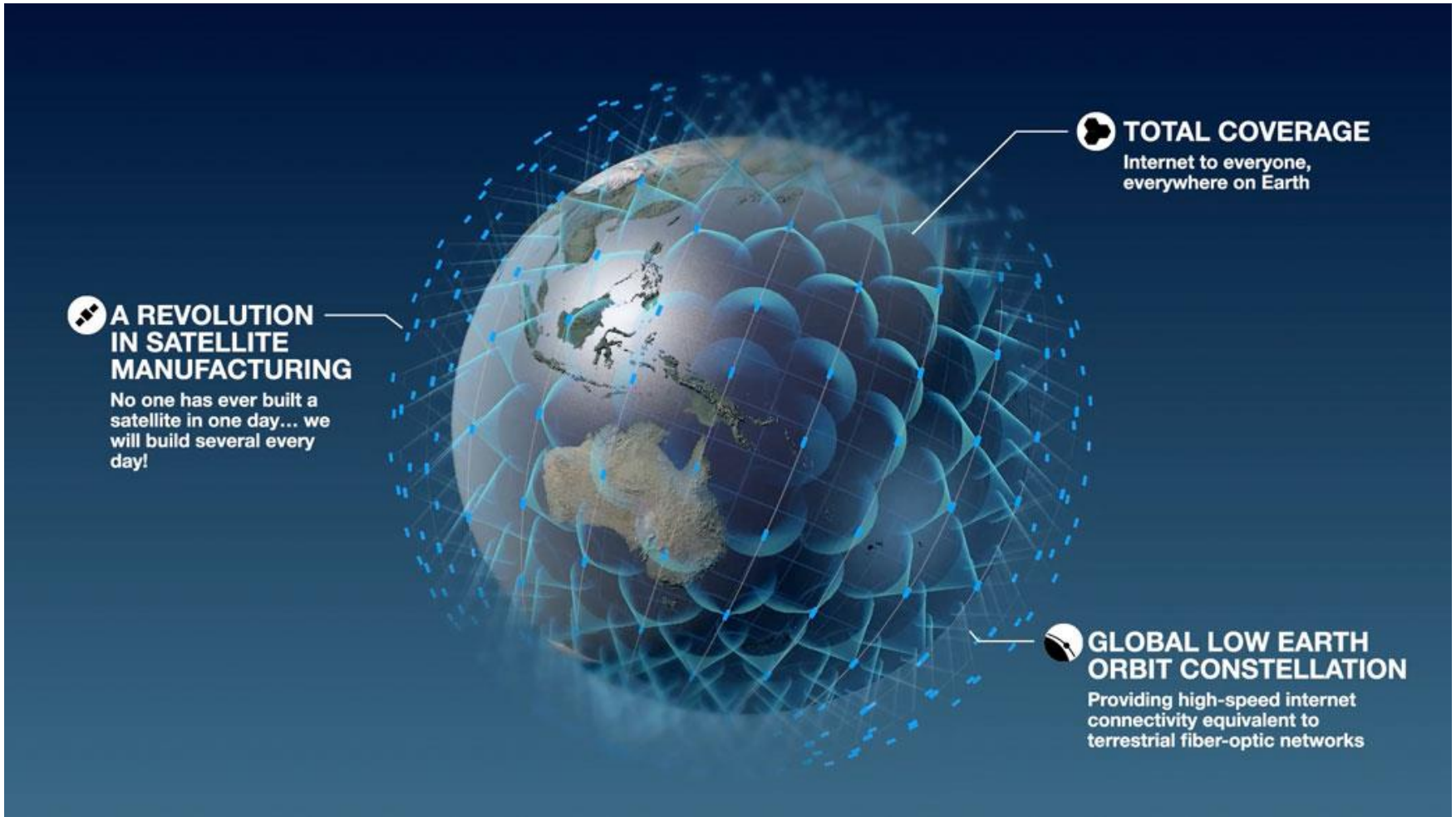






OneWEB

- > 2$B investment, >900 small satellites (350 kg), broadband comms
- US company, Airbus (France) manufacturer
- Satellite assembly in Toulouse and USA (Canaveral), 2 satellites/per day!!!



Earth-I (UK) Constellation

earth i | VIVID-I

- €10 Million VC funding raised to date
- Platforms built by SSTL (UK)

ICEYE (Finland)

- 25 satellite 6U Cubesat constellation in 600 km orbit, first satellite in 2018
- 5-10m resolution
- Start up company based in Finland, has raised over €15 million VC

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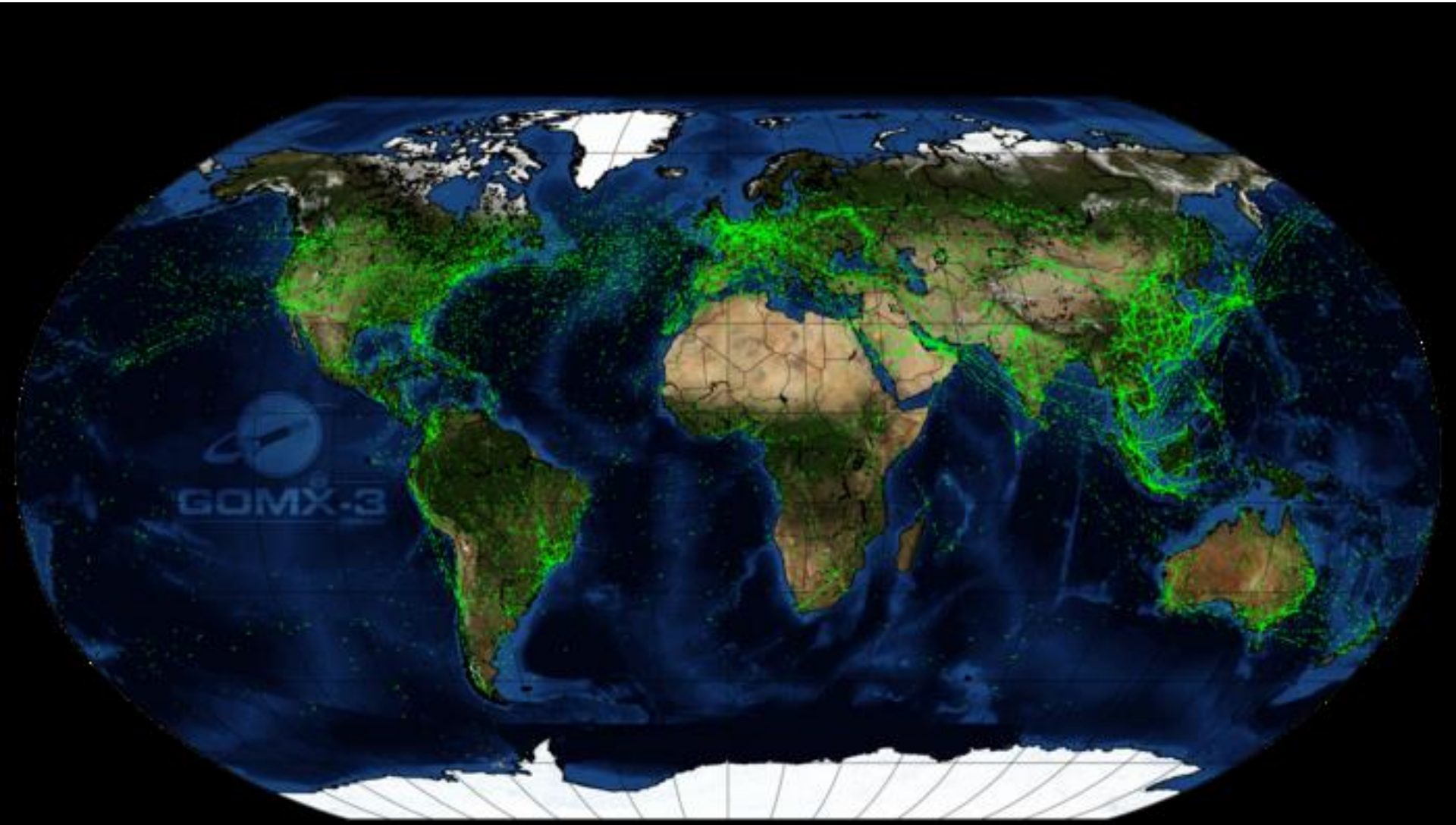
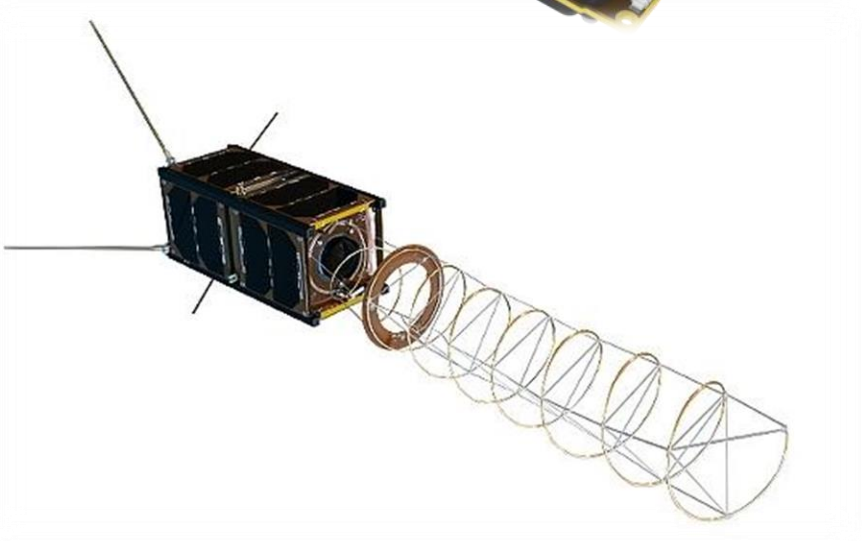
AIS, ADS-B, VTS Ship Tracking with nanosats



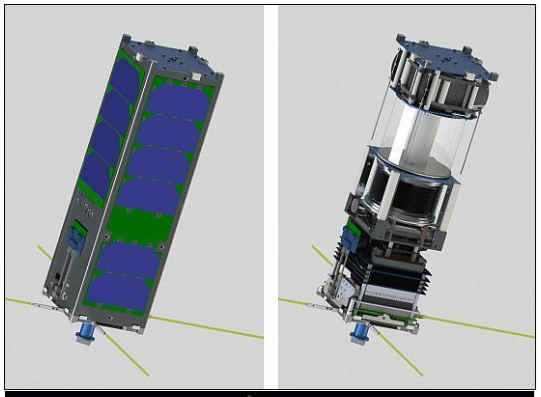
GOMSpace GOMX-3 ADS-B Flight Tracking in 2016

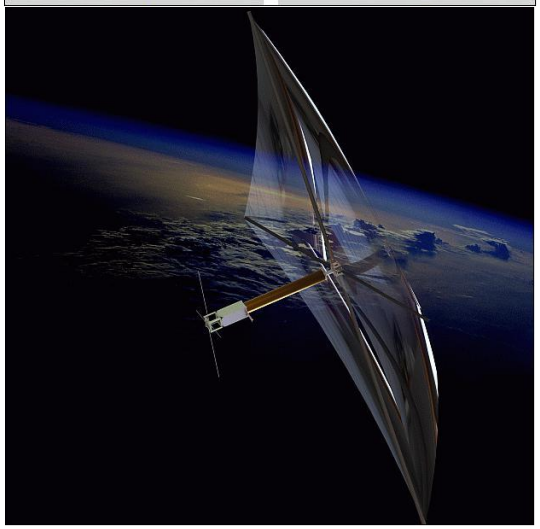
AIS, VTS nanosat Constellation

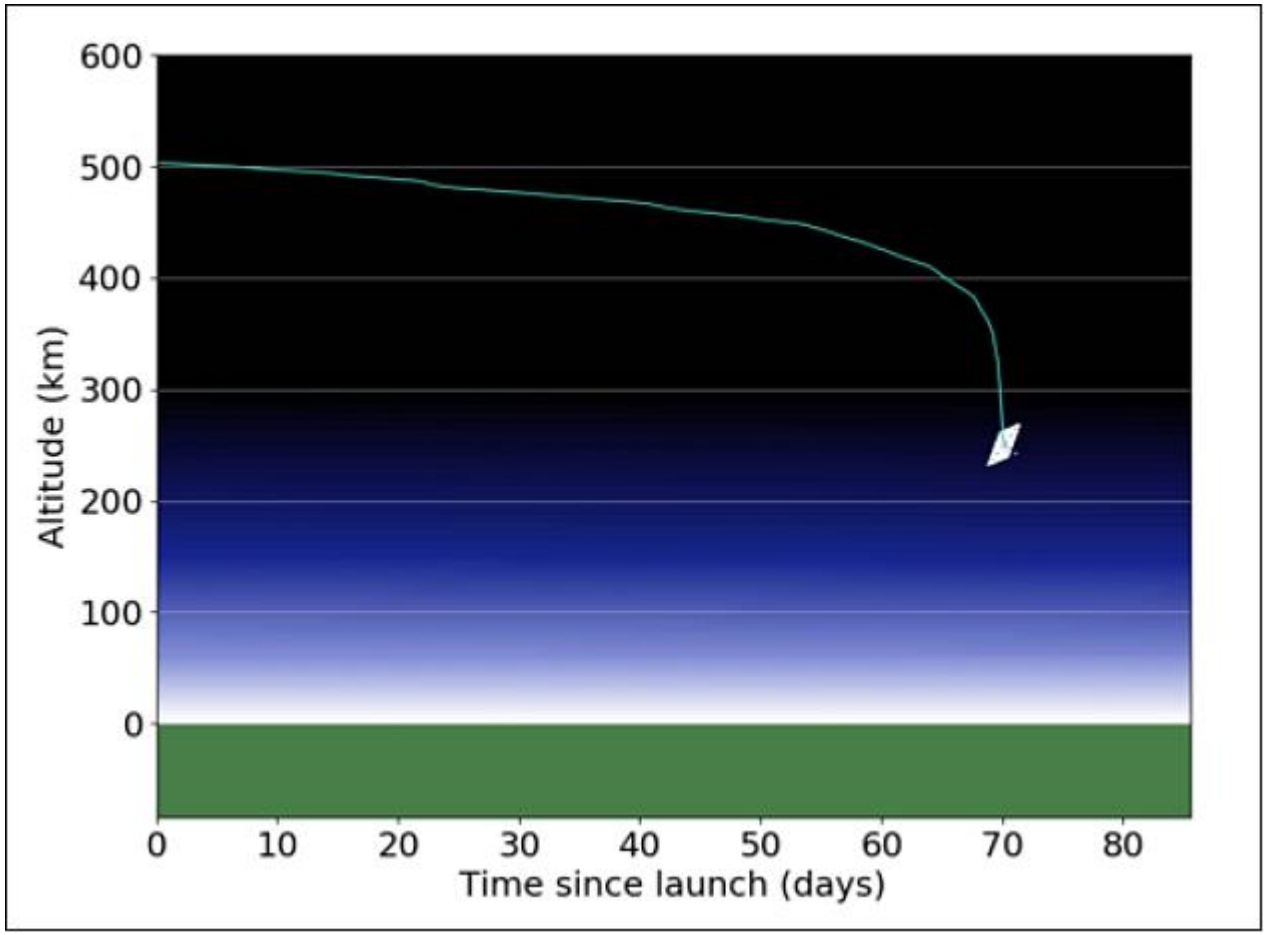
- Use Software Defined Radios (SDR) for AIS, VTS and spectrum monitoring



InflateSAIL Deorbiting System/Mission







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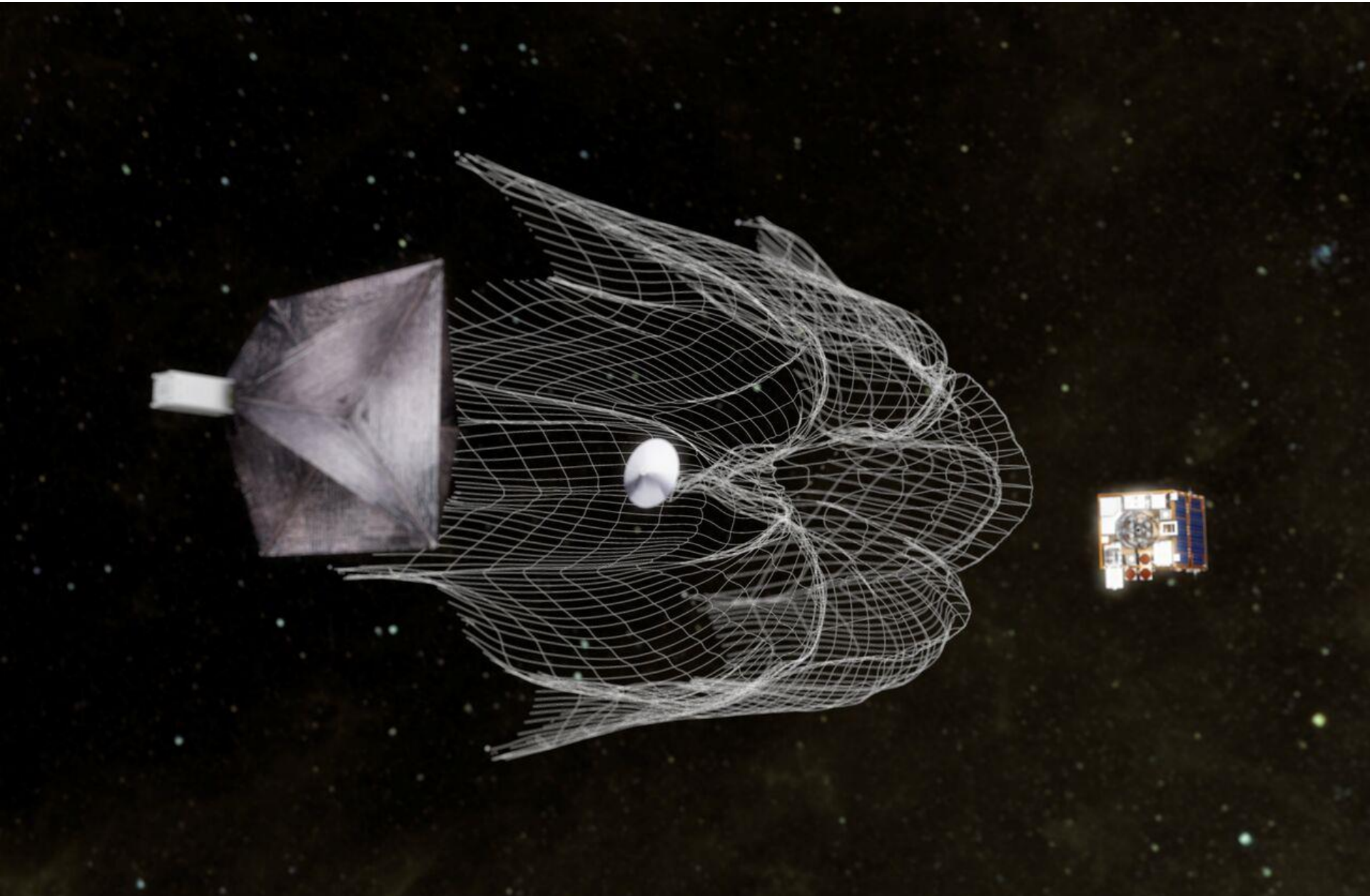
Technology Demonstration



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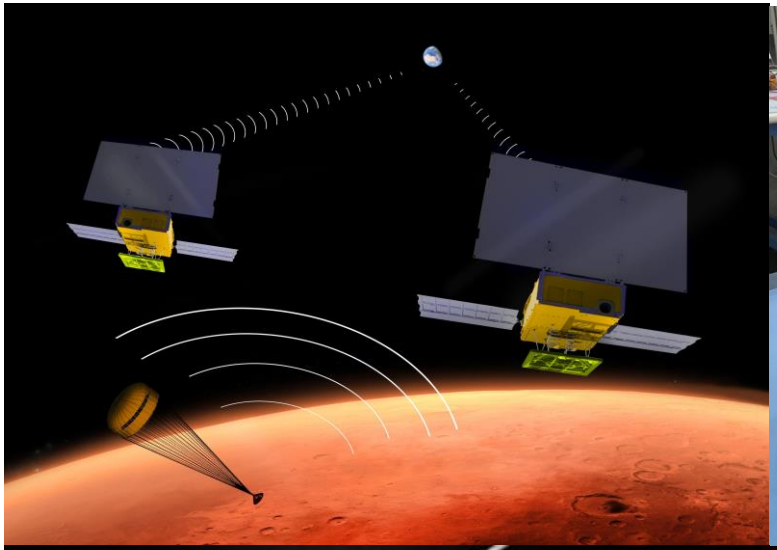
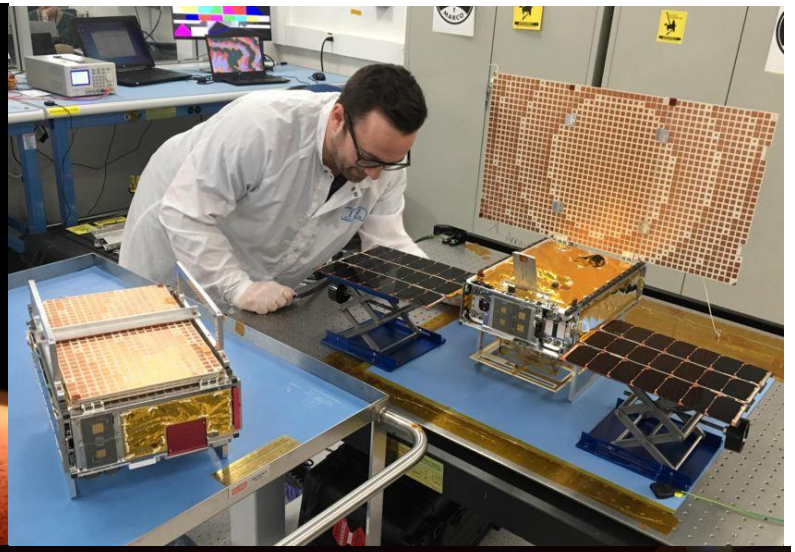
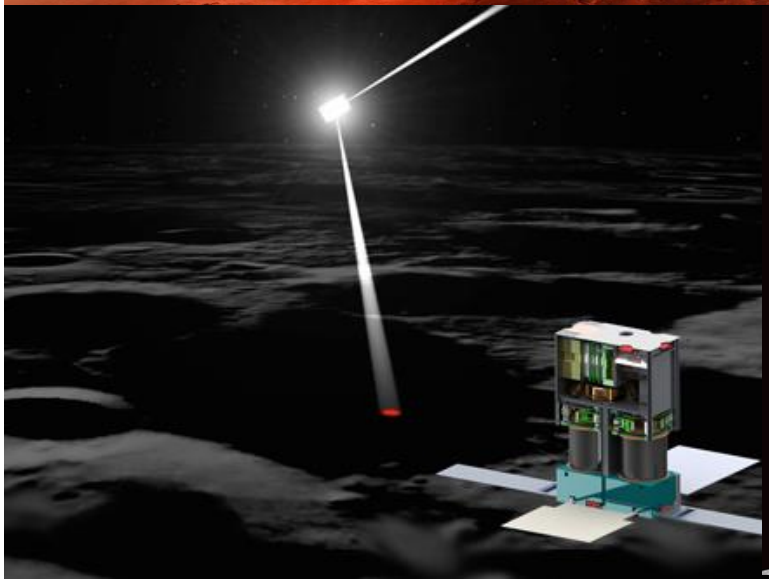
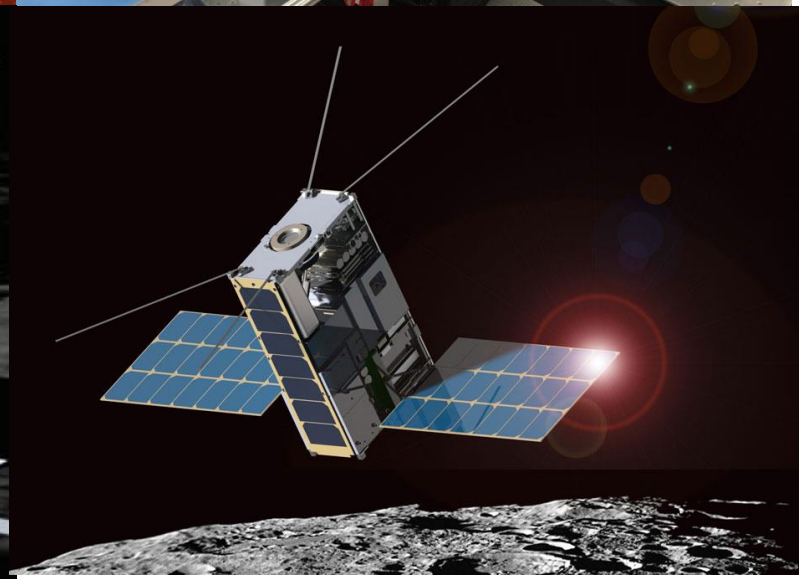
RemoveDEBRIS: Debris Capture with Net

Space Exploration Nanosats









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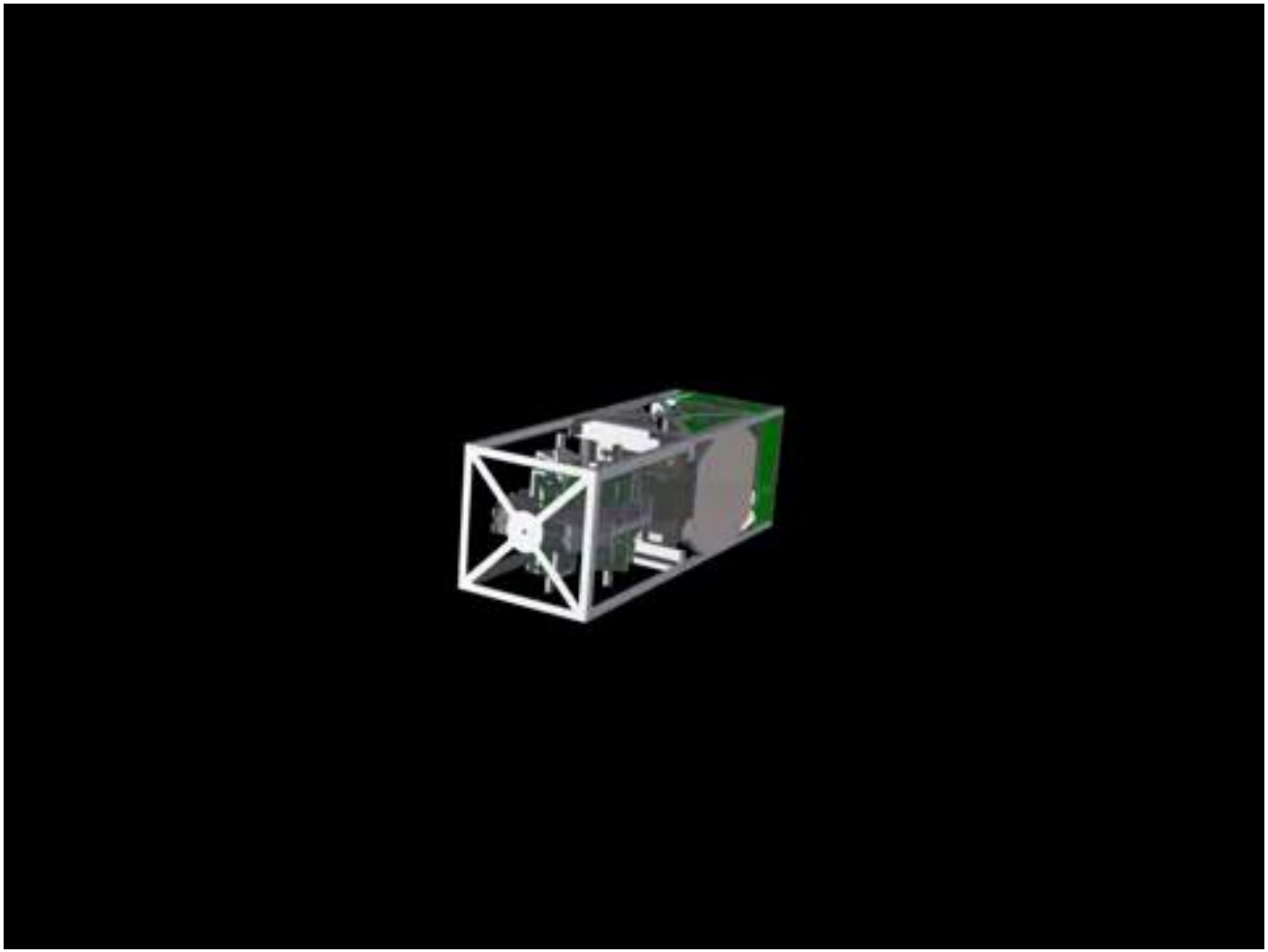
Deployable Optics Nanosat



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Reconfigurable Space Telescopes (e.g. Persistent Monitoring from GEO)

Συμπεράσματα

- Μικροδορυφόροι:
  - Industry 4.0 (revolution), NewSPACE (new start ups/products)
  - Small entities/academia can easily get involved
  - Can get an 'idea' to orbit in months
- Δυνατότητες σημαντικών συνεργειών με Ελληνικά Πανεπιστήμια / Ελληνική Βιομηχανία
  - Δημιουργία νέων υπηρεσιών/προϊόντων σε διεθνές επίπεδο
- Δημιουργία νέων θέσεων εργασίας/οικοσυστήματος


Ευχαριστώ